

REPORT



METROPOLITAN SEWERAGE COMMISSION

OF

NEW YORK

1910

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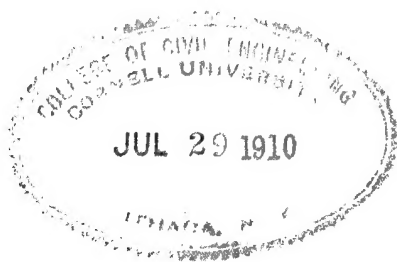
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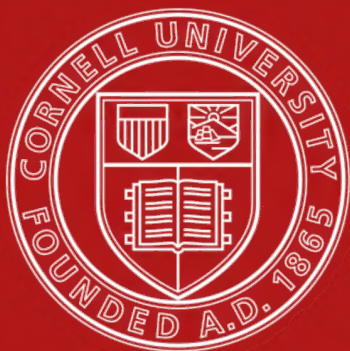
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SEWERAGE AND SEWAGE DISPOSAL IN THE METROPOLITAN DISTRICT OF NEW YORK AND NEW JERSEY

REPORT

OF THE

METROPOLITAN SEWERAGE COMMISSION OF NEW YORK

Appointed under Chapter 639, Laws of 1906, as amended by
Chapter 422, Laws of 1908 of New York State

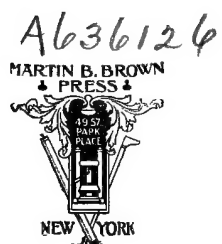
APRIL 30, 1910

GEORGE A. SOPER, President,
JAMES H. FUERTES, Secretary,
H. DE B. PARSONS,
CHARLES SOOYSMITH,
LINSLEY R. WILLIAMS,

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LETTER OF TRANSMITTAL

NEW YORK, April 30, 1910

Honorable WILLIAM J. GAYNOR, Mayor of The City of New York,
Executive Chamber, City Hall, New York City.

SIR: We submit herewith the report of the Metropolitan Sewerage Commission of New York, which was created to study the conditions of sewerage and sewage disposal in the metropolitan district of New York and formulate a general plan or policy for protecting and improving the sanitary condition of New York harbor and neighboring waters in accordance with an Act of the State Legislature, Chapter 639, Laws of 1906, amended by Chapter 422, Laws of 1908.

Most of the work here reported was accomplished after the membership of the Commission was reconstituted in January, 1908, although care has been taken to utilize all useful information collected prior to that date by members of this Commission and others.

Upon its reconstitution the Commission estimated that it would take about two years of time and an expenditure of \$75,000 to complete the investigation for which it had been created. It is a source of gratification to report that the work has been finished in accordance with this estimate, notwithstanding delays, aggregating thirteen months, before an appropriation could be obtained and salaries paid to the assistants whom it was necessary to employ for clerical and professional work.

Part of the success of the investigation has been due to co-operation received from various departments of The City of New York and the United States Government. The United States Coast and Geodetic Survey aided in studies of tides; the Corps of Engineers United States Army furnished data concerning solid deposits and dredging operations in the harbor; the Lighthouse Board permitted tests of the water to be made at their stations; the Department of Docks and Ferries of The City of New York gave the use of laboratory space; the Department of Health of The City of New York furnished statistical information and made special bacteriological analyses; the Department of Street Cleaning of The City of New York supplied information concerning the quantities of garbage dumped at sea; the New York Zoological Society furnished laboratory space and tanks for experimental purposes in the New York Aquarium. The Borough Presidents of New York and the chiefs of sewer bureaus in the many cities and towns in the metropolitan district courteously afforded opportunities to collect valuable data.

Respectfully submitted,

METROPOLITAN SEWERAGE COMMISSION OF NEW YORK,

GEORGE A. SOPER,
JAMES H. FUERTES,
H. DE B. PARSONS,
CHARLES SOOYSMITH,
LINSLEY R. WILLIAMS.

FOREWORD

The following report is divided into three sections designated respectively Part I, Part II and Part III.

Part I is a summary of the whole report. It contains a brief statement of the nature and extent of the investigations conducted by the Commission, the principal results of the investigations and the more important of the Commission's recommendations.

Part II is a summary of the investigations. It gives the main facts and results in convenient form for reading and reference.

Part III contains a classified digest of the data collected during the Commission's investigations.

It has been found impracticable to publish full tabulations of the analyses and observations; these would have occupied several hundred pages. It is believed that the summaries presented in the various chapters of Part III will prove sufficient for most purposes; officials who desire to study the observations and analyses in detail may have access to the original data upon request.

The report does not contain a full index. An extensive table of contents, combined with the free use of italic subheads throughout the text, will enable ready reference to be made to the different subjects dealt with in the report.

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PART I

Summary of Report

PART I

SUMMARY OF REPORT

In 1906 the Legislature directed The City of New York to appoint the Metropolitan Sewerage Commission of New York, specified the qualifications which the members must possess and the work which the Commission was to perform. In 1908 the Commission was reconstituted and its life continued to May 1, 1910.

DESCRIPTION OF THE INVESTIGATIONS

PLAN OF INVESTIGATIONS

After considering how the sewage disposal problems of other cities had been met, the Commission laid out the line of investigation which was to be pursued.

The immediate objects of the programme were:

First. To establish the facts attending the discharge of the sewage;

Second. To determine the extent to which these conditions were injurious to the public health and welfare; and,

Third. To ascertain the way in which it would be necessary to improve the conditions of disposal in order to meet the reasonable requirements of the present and future.

ANALYTICAL WORK

The capacity of the waters for harmlessly assimilating sewage was a subject which had to be taken carefully into account in view of the great cost of the works which would be necessary if all sewage was to be kept from entering the harbor. For this reason there had to be undertaken extensive analytical studies to show the conditions of assimilation under various circumstances. The studies made included over 5,000 analyses of water or solid deposits. Samples from all parts of the harbor were examined chemically, bacteriologically and microscopically. All stages of tide and all seasons of year are represented in the results.

REPORT AND RECOMMENDATIONS

POPULATION AND SEWERAGE

A study was made of the sewerage systems of New York and the other cities within twenty miles of New York City Hall with estimates of the quantities of sewage discharged from the houses and streets by the human and animal populations.

Estimates of future populations were compiled for the several municipalities in the metropolitan district, including a critical review of estimates by other authorities.

EXPERIMENTS AND TESTS

Experimental studies were made to determine the possibility of diffusing and disposing of sewage through the waters of the harbor without offense or danger to the public welfare. These experiments were begun in the Commission's laboratory, were followed on a larger scale in tanks in the New York Aquarium, and were concluded in the open waters of the harbor by the aid of tank steamers, pontoons, pumps and other apparatus.

To determine the extent to which public bathing places and shellfish beds were polluted by sewage, powerful dyes were placed in the sewers, and the course subsequently taken by the discolored sewage was then traced.

STUDIES OF TIDAL PHENOMENA

A theoretical and practical investigation of the tidal phenomena of New York harbor was carried on in co-operation with the United States Coast and Geodetic Survey. In this study especially constructed floats were set adrift and note was made of the courses which they took under the influence of the tidal currents. The conditions were studied in all parts of the harbor. The floats were followed by boats, sometimes for several days in succession.

ACTION WITH RESPECT TO TRUNK SEWERS

The Commission endeavored to ascertain the essential details of the trunk sewerage projects which had been proposed by various authorities to collect the sewage of inland municipalities for discharge into New York harbor. As a result of these studies the Metropolitan Commission registered a protest with the State Commissioner of Health and State Engineer and Surveyor against the Bronx valley project, and repeatedly expressed an adverse opinion on the discharge of untreated sewage from the Passaic valley sewerage district into New York bay.

An examination into the legal jurisdiction now exercised over the harbor waters was undertaken in order to aid in determining the best form of administration for a comprehensive system of sanitary conservancy.

CO-OPERATION INVITED FROM NEW JERSEY

At the instance of this Commission, and in accordance with the legislative Act which provided for its creation, an invitation was sent in 1908 by the Secretary of State of New York to the Governor of New Jersey inviting New Jersey to co-operate in the work which the Metropolitan Sewerage Commission of New York was performing, but this invitation was without result.

RESULTS OF THE INVESTIGATION

Briefly stated, the Commission has found that the methods by which sewage is disposed of in the metropolitan district of New York and New Jersey call for immediate and far reaching improvement.

The problem of disposing of the sewage of this metropolitan district has taken on a new aspect in recent years owing to the large increase of population which has occurred. The waters within fifteen miles of Manhattan Island, which formerly were of ample capacity to receive and dispose of the sewage which was discharged into them, are rapidly becoming overburdened with the wastes.

DANGERS FROM BATHING AND FROM SHELLFISH

Bathing in New York harbor above the Narrows is dangerous to health, and the oyster industry, already driven to the outer limits of the district, must soon be entirely given up.

LOCAL NUISANCES

The Passaic river, the Rahway river, the Bronx river, Gowanus and Newtown creeks, and the Harlem river have become little else than open sewers. Innumerable local nuisances exist along the waterfronts of New York and New Jersey where the sewage of the cities located about the harbor is discharged. Unless prevented by a proper system of regulation, these nuisances must inevitably increase with the increase in the quantity of sewage.

CONDITION OF WATER IN MAIN CHANNELS

Not only does the discharge of sewage now produce objectionable conditions near the points of outfall, but the water which flows in the main channels of the harbor above the Narrows and in the East and Hudson rivers is more polluted than considerations of public health and welfare should allow.

The studies made by this Commission show that the digestive capacity of this water for sewage is so reduced by pollution that restrictions should at once be placed upon the discharge of sewage therein to prevent the harbor from becoming positively offensive.

It has been proved that, contrary to popular belief, the tidal currents do not flush out the harbor satisfactorily, but cause the sewage to oscillate back and forth near its points of origin.

ADDITIONAL POLLUTION FROM TRUNK SEWERS

In addition to the objectionable conditions produced by the discharge of sewage from the cities surrounding the harbor, a number of extensive trunk sewerage projects have lately been constructed or designed to carry the sewage of inland municipalities for disposal into the waters in the immediate vicinity of The City of New York. These projects include the Joint outlet sewer of New Jersey, which drains an area of 37 square miles and discharges at Elizabethport opposite the Borough of Richmond; the Passaic valley sewerage project, which will drain 103 square miles and discharge at Robbins reef within a few hundred feet of New York city line, and the Bronx valley sewer, which will drain 35 square miles and discharge into the Hudson immediately above the New York city line.

These trunk sewers ultimately would add greatly to the polluting matter entering the harbor. The total capacity of the works mentioned is seven hundred million gallons of sewage per day. By the time these sewers are running at their full capacity the quantity of sewage from The City of New York will be at least twice what it is to-day, or, approximately, one thousand million gallons. It should be unnecessary to sound a clearer warning of the future condition of the harbor than these facts indicate.

ANSWERS TO QUESTIONS RAISED BY THE LEGISLATURE

The following are the specific questions raised by the Legislature in the act which provided for the creation of the Metropolitan Sewerage Commission of New York and the Commission's answers to these questions:

Question 1. Is it desirable and feasible for The City of New York and the municipalities in its vicinity to agree upon a general plan or policy of sewerage and sewage disposal which will protect the waters of New York bay and vicinity against unnecessary and injurious pollution by sewage and other wastes?

Answer. It is not possible to protect the waters of New York bay and vicinity by intercity agreement. There are about eighty municipalities concerned, and the subject would be beyond their capacity to regulate properly.

Question 2. What methods of collecting and disposing of the sewage and other wastes which pollute, or may eventually pollute, the waters contemplated in this act are most worthy of consideration?

Answer. The methods of collecting and disposing of sewage in the metropolitan district most worthy of consideration are district collecting sewers leading to local works for purifying the sewage to a greater or lesser degree, depending upon the facility with which the effluent can then be disposed of

without injury to the public welfare. The principles of purification most worthy of consideration are sedimentation, screening, filtration and sterilization applied with such modifications as experience in other places and local circumstances indicate.

Question 3. Is it desirable to establish a sewerage district in order properly to dispose of the wastes, and adequately protect the purity of the waters, contemplated in this act, and, if so, what should be the limits and boundaries of this sewerage district?

Answer. It is desirable to establish a sewerage district in order properly to dispose of the wastes, and the Commission believes that this would be the best way in which the sanitary condition of the harbor could be conserved. The most desirable limits for the sewerage district would include a territory of about seven hundred square miles, about half of which would be in New York and half in New Jersey.

If it is not possible at the present time to create an interstate sewerage district, a metropolitan sewerage district and commission for New York State should be created without delay. The limits and boundaries of this district should include The City of New York and those parts of Nassau and Westchester counties the sewage of which flows, or might be made to flow, into the harbor.

Question 4. What would be the best system of administrative control for the inception, execution and operation of a plan for sewerage, and ultimate sewage disposal, of a metropolitan sewerage district; whether by the action of already existing departments and provisions of government, by the establishment of separate and distinct sewerage districts and permanent commissions in each State, by one interstate metropolitan sewerage district and commission to be established by agreement between the two States, this agreement if necessary to be ratified by Congress, or by other means?

Answer. The best system of administrative control would be an interstate sewerage commission, established by Acts of the Legislatures of New York and New Jersey, these Acts to be confirmed by Congress. If this joint action between the two States cannot be brought about, or is not considered to be feasible at the present time, the duty of carrying out this policy of conservancy, as far as it is possible to do so, should be placed in the hands of a commission for the metropolitan territory of New York, the expectation being that New Jersey will later create a similar commission to co-operate in regulating the conditions of sewage disposal in the interest of the common welfare.

Existing departments and provisions of government could not appropriately nor adequately deal with this question. The problems to be confronted are of unusual difficulty and complexity, owing to the great extent of territory (approximately seven hundred square miles), the large population (approximately five million inhabitants to-day, and more than twice this number by 1940), and the many hydrographic, sanitary and economic questions which must be considered and adjusted between the several localities concerned.

A separate and distinct sewerage district and a permanent commission in each State would be an effective instrument toward the accomplishment of the end desired, and it would probably be more feasible at this time to create two separate commissions than a single metropolitan commission having jurisdiction over both States. If two commissions could be so formed as to act in harmony, the effect would be nearly that of one interstate commission.

RECOMMENDATIONS

The remedy which the Commission recommends is the result of careful consideration of various plans of conservancy which have been adopted in other populous centers in Europe and America.

The Commission is of opinion that the metropolitan territory should be divided into sections, with boundaries to be determined partly by the quantities of sewage produced, partly by the facilities which are open in the several localities for disposing of the wastes in a sanitary manner and partly by considerations of cost.

No system of conduits designed to collect the sewage of the whole metropolitan district and carry it to a single point for disposal is practicable. To a considerable extent purification works, embodying the principles of sedimentation, screening and filtration should be employed.

There should be prepared an outline plan to which all future sewerage work should conform so far as that work relates to the ultimate disposal of sewage.

There should also be plans, drawn in some detail, for the disposal of the sewage of individual districts, beginning with those where the need for improvement is greatest.

This programme involves for the immediate future no expenditure or commitment of City or State beyond the expenses of the commission for the preparation of plans.

In addition to the preparation of a general plan for conservancy, the Metropolitan Sewerage Commission makes the following specific recommendations:

A large portion of the sewage now discharged into the Harlem river and into the upper part of the East river should be intercepted and taken elsewhere for disposal in order to do away with the nuisances now existing in these streams.

A special detailed study should be made immediately of improved sewerage and sewage disposal for the portions of the Boroughs of Queens and Brooklyn bordering on Jamaica bay and the East river at its entrance to Long Island Sound, with a special reference to plans for the interception of the sewage and the determination of the kind and degree of purification required in each locality.

Plans should be prepared as soon as practicable, in conjunction with the Bureau of Sewers and the sewer division of the Public Service Commission for the reconstruction of the sewers of Manhattan on the separate plan, the desirability of following this recommendation being dependent on the construction of additional rapid transit subways on streets and avenues traversing the city from north to south, the new plans to preserve for use the existing sewers to as great an extent as possible.

With respect to large trunk sewer projects designed to discharge into New York harbor, such as the Passaic valley and Bronx valley sewers, this Commission

recommends that an adequate degree of purification of the sewage be insisted on under a form of agreement which can be practically and legally enforced.

The agreement entered into in 1910 between the United States Government and the Passaic Valley Sewerage Commissioners contains provisions inimical to the interests of the City of New York and the other cities bordering on New York harbor in New York State as well as in New Jersey and it is recommended that the State of New York continue to press the suit, from which the United States Government has withdrawn, against the State of New Jersey and the Passaic Valley Sewerage Commission, and that the City of New York apply to the Supreme Court of the United States for permission to intervene and become a party to this suit to the end that proper provision may be made to protect the public interests and the health and welfare of the population of the entire metropolitan district.

The Commission recommends that great care be exercised in the location of public bathing establishments to avoid unsafe localities, and that the free floating bathing establishments around the water front be gradually abolished, properly planned interior bathing establishments, supplied with pure water, being substituted therefor.

A study of the methods used in designing, as well as in constructing sewers in the metropolitan district has shown the Commission that considerable confusion and waste of public funds results from the diversity of practice which now exists in different sections of the district. It is recommended that these matters be systematized as much as practicable, and sewer designs reduced to standard forms, where feasible.

It has also been found that there is lack of co-operation between the different departments of the City which results in high maintenance costs for sewers. This is particularly true with respect to the relations between the Bureaus of Sewers, the Department of Docks and Ferries, the Department of Street Cleaning, the Department of Water Supply, Gas and Electricity, and the Department of Finance and the Public Service Commission. Closer co-operation between these departments and bureaus should be established.

The Commission recommends that proper legal steps be taken to give the inspectors of the Bureaus of Sewers the right of entry for the purpose of inspecting house and sewer connections in private buildings where these are connected with public sewers. This right would make possible the protection of the public sewers against the discharge therein of acids, hot liquids, steam and strong solutions which tend to destroy the materials of which the sewers are constructed.

The data upon which the foregoing recommendations are based will be found in Parts II and III of this report.

IN CONCLUSION

In accordance with the requirements of the Legislature, the Metropolitan Sewerage Commission has made a thorough investigation into the present and probable future condition of the waters of New York bay and vicinity and has *formulated a general plan or policy* by which the sanitary condition of the harbor can be permanently protected and improved.

It is recommended that the duty of *carrying out the policy of conservation here proposed* be placed in the hands of a special board of commissioners.

The first duty of the commission proposed would be to utilize the information which has been collected and plan the work necessary to carry out the general recommendations here made.

In conclusion, the Commission desires to state with all possible clearness its sense of the importance of putting a stop to the unrelated and unsanitary methods of sewage disposal which are being followed in the metropolitan territory of New York and New Jersey and to urge that prompt action be taken to establish an effective system of conservancy to protect and improve the condition of the harbor.

PART II

Summary of Investigations

PART II
SUMMARY OF INVESTIGATIONS
CHAPTER I
REPLIES TO THE SPECIFIC QUESTIONS IN THE ACT CREATING
THE METROPOLITAN SEWERAGE COMMISSION

SECTION I
THE METROPOLITAN DISTRICT

LAND AND WATER AREAS

The legislative Acts under which the Metropolitan Sewerage Commission of New York was created required that the Commission should investigate whether it was desirable to establish a sewerage district in order properly to dispose of the wastes and adequately protect the purity of the waters contemplated in this Act, and if so, what should be the limits and boundaries of the district.

Extent of the District. The Commission's studies indicate that a single sewerage district is desirable and that it should include about 700 square miles in the States of New York and New Jersey, all within about 20 miles of the City Hall in Manhattan. The boundary should be established with reference to natural watersheds and with regard to the distribution of population rather than with respect to municipal or State limits. The boundaries which were established for the purposes of the Commission's studies include the village of White Plains on the north, and the mouth of the Raritan river on the south, and from the limits of the City of New York on the east to the municipalities of Paterson, Summit and Perth Amboy on the west. This territory lies within a distance which ranges between 15 and 20 miles of the City Hall on Manhattan Island. The territory included within this boundary is called in this report the metropolitan district.

WATERS OF THE DISTRICT

Hudson River. The district is divided into two nearly equal parts by the Hudson river. The Hudson averages one mile in width and flows in a southerly direction to the Upper bay and thence, through the Narrows, to the Lower bay and the Atlantic ocean.

The current in the Hudson river oscillates back and forth under tidal influence, the flow past Manhattan not being continuously toward the sea. Sea water, mingled with more or less land water, flows up the Hudson many miles above the limits of the metropolitan district.

East River. Passing along the east side of Manhattan Island, and separating it from the end of Long Island, is the East river which connects the waters of the Upper bay and Long Island Sound. Between the Manhattan and the Brooklyn shores this river varies from about 1,500 feet to more than three-fourths of a mile in width. After passing Hell Gate it attains, at Flushing bay, a width of over two miles, and flows into Long Island Sound at Throgs Neck and Willets Point.

The water in the East river is kept in motion by tidal influences in Long Island Sound and New York harbor. The water oscillates back and forth in accordance with the differences in elevation between the waters in the Sound and those in the bay. The East river is not strictly speaking a river, but a strait.

Harlem River. Joining the East and Hudson rivers is the Harlem, a stream similar in some respects to the East river, the motion of the water through it depending upon the differences in elevation between the East river and the Hudson river at different times. The differences in elevation between the Hudson river where the Harlem river enters it, the East river where it enters Long Island Sound, and the Upper bay, are due to the fact that high or low tides are not reached at these three points at the same time, and also to the fact that the amplitudes of the tides at the three points are different.

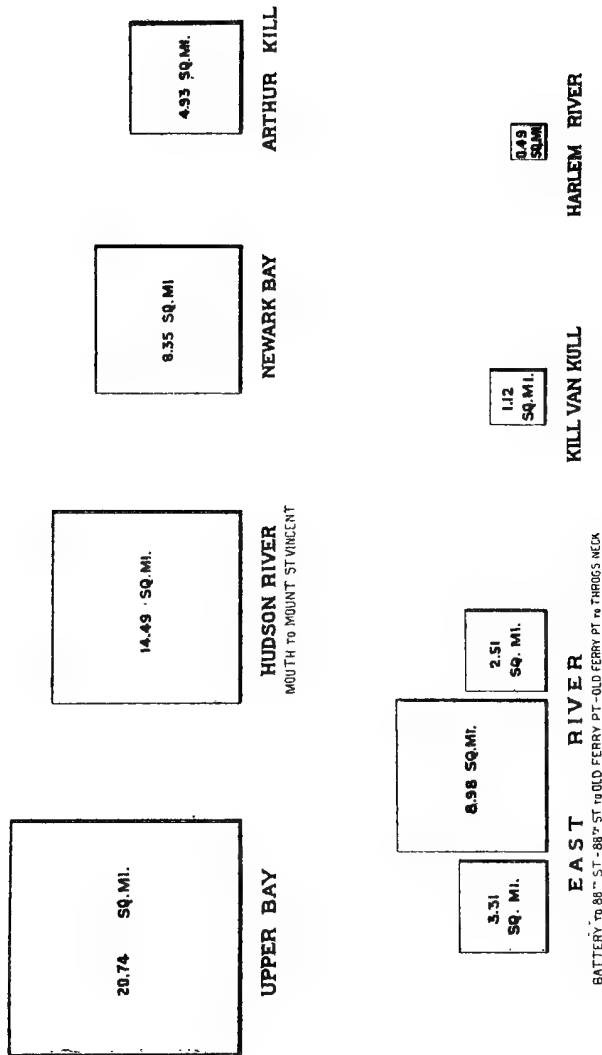
Outer Harbor, Jamaica Bay and Atlantic Ocean. The southern shores of the Boroughs of Brooklyn and Queens lie along the waters of the outer harbor, Jamaica bay, and the Atlantic ocean, Jamaica bay being a large, relatively shallow inland tidal basin covering, with its tributaries, some 19.27 square miles.

The Kills. The Borough of Richmond is entirely surrounded by water, Newark bay, Kill van Kull and Upper bay bounding it upon the north, the Lower bay bounding it upon the east and south and the Arthur Kill bounding it upon the west.

Newark Bay. The New Jersey district is traversed by three comparatively small streams, two of which empty into the head of Newark bay. Newark bay is some six miles long and averages nearly one mile and a half wide. It lies parallel to and is separated from the Upper New York bay by the peninsula of Bayonne, which, north of Constable Hook, its southern terminus, is about three-fourths of a mile in width.

The principal cities and towns in the New Jersey district, excluding Jersey City, Hoboken, Weehawken and a few small settlements along the Hudson river, lie in the valleys of the Hackensack and Passaic rivers. The Hackensack and the Passaic flow through the district in a direction somewhat westerly of south, and within the metropolitan district lie but a few feet above sea level.

Small Estuaries. The shores of Long Island, New Jersey, The Bronx and the main land to the east of The Bronx are deeply indented by bays and small estuaries, such



WATER SURFACES IN NEW YORK HARBOR

as Newtown creek, Flushing creek, the Rahway river and Eastchester river. Some of these streams have been canalized, as Gowanus, for example.

Depths of Waters. In the Narrows, where the Upper bay joins the Lower bay, the depth of the main channel is in places as great as 120 feet; in the Hudson the channel varies from 60 to 75 feet in depth far up the river. The main channel, though broad, is fairly well defined through the Upper bay, the western edge being practically a continuation of the river bank between the piers of the Central Railroad of New Jersey in Jersey City and Tompkinsville on Staten Island. The flats to the west of this channel, which are extensive in area, are as a rule submerged less than 12 feet below low water. The width of the main channel through the Upper bay is fixed in a general way by a line approximately parallel to the western limit starting from the western end of Governors Island and extending to the east side of the Narrows.

The East river is generally less than 60 feet deep, but in places, particularly at Hell Gate, some parts of the narrow channels are 150 feet in depth. In the Harlem river and Spuyten Duyvil creek the water is but 12 to 20 feet in depth.

Newark bay has a depth of 12 feet, or less, excepting at the outlet connecting with Kill van Kull, where the water is 25 to 30 feet deep, as is also the Kill van Kull. The Arthur Kill is generally shallow.

Areas of Water Surfaces. Of the 700 square miles included within the boundaries of the metropolitan district, the water surfaces cover an area of 180 square miles, or 26 per cent. The principal areas are:

Lower bay and Atlantic ocean.....	83.00 square miles
Upper bay	20.74 square miles
Jamaica bay	19.27 square miles
East river	14.80 square miles
Hudson river	14.50 square miles
Long Island Sound.....	12.80 square miles
Newark bay	8.35 square miles
Arthur Kill	4.93 square miles
Kill van Kull.....	1.12 square miles
Harlem river .....	.49 square miles
	<hr/>
	180.00
	<hr/>

DISTINCTIVE TOPOGRAPHICAL CHARACTERISTICS

Where the Hudson river enters the metropolitan district it is flanked on the west side by the Palisades which reach at the northern limit of the district a height of over 400 feet above the river. The height of these cliffs gradually decreases to about 200

feet opposite Forty-second street, Manhattan, from which point it gradually diminishes to a few feet above sea level at Jersey City.

In the Borough of Manhattan the most extensive heights extend from Riverside Park to Tubby Hook just below the place where the Harlem river joins the Hudson. These heights extend to the southwest with a gradually reducing elevation; the backbone of Manhattan is practically along the line of Broadway.

The district lying to the north of the Harlem, on the east bank of the Hudson including The Bronx is of a rolling nature reaching to heights of a little over 300 feet above sea level. The balance of the metropolitan district in The Bronx is characterized by four nearly parallel valleys which extend north and south. Tibbetts brook lies in the valley nearest to and one and a half miles east of the Hudson; it empties into Spuyten Duyvil creek. The Bronx river lies in the next valley, about three miles east of the Hudson, and empties into the East river between Hunts Point and Classon Point. Hutchinson creek lies in a valley five miles east of the Hudson river passing between Mt. Vernon and New Rochelle and emptying into Eastchester bay and Long Island Sound; Sheldrake river emptying into Long Island Sound near Larchmont, occupies the fourth valley. The ridges between these valleys rise gradually from Long Island Sound to an elevation of about 300 feet in the region of Scarsdale and White Plains.

In Brooklyn and Queens Boroughs the ridge of the terminal moraine reaches an elevation of about 180 feet above sea level and follows a line stretching from Bay Ridge through Ridgewood and Richmond Hill to a point about one-half a mile north of Jamaica. The southerly or southeasterly face of this moraine is steep, the elevations at its foot, a distance of one-half mile or so from the ridge crest being less than 100 feet above sea level. From the southerly foot of the ridge the ground slopes gently down to tide level at Jamaica bay, Sheepshead bay and Gravesend bay. To the north of the ridge the ground, as a rule, slopes gradually and uniformly toward the northwest to East river and Long Island Sound.

In the center of the Borough of Richmond there are many points that reach a height of 300 feet above sea level. From these the ground slopes regularly toward the marshes and tidewater on the west and north and abruptly down to sea level on the east side.

In the New Jersey territory the most prominent topographical feature, outside of the Palisades and the Bergen Hills, is First Watchung Mountain, which, back of Montclair, reaches a height of about 650 feet. It is broken through by a pass at Great Notch and also by the valley in which the Passaic river swings to the east around the city of Paterson. Between Watchung Mountain and the Bergen Hills the

country is comparatively flat, seldom rising to a greater height than 200 feet and lying generally at an elevation of not over 100 feet above sea level between the edge of the salt marshes and the mountains to the west.

The City of New York and the other cities along the tidal waters in the metropolitan district form the greatest commercial center in the United States. In 1900 this district had about 46 per cent. of the import and export trade of the nation. The cities on the lower Hudson are connected with distant cities to the north, south, east and west by trunk lines of railroads of which the largest number terminate on the New Jersey side of the Hudson. Within a short time, however, the Pennsylvania Railroad tunnels extending across the Hudson from their New Jersey terminal to New York and thence under the East river to Long Island will be in operation. In addition to this ocean and railway traffic the Hudson river has tide water connection to Albany and Troy and a prospective connection thence by means of the barge canal with the Great Lakes for boats of considerable tonnage.

POPULATION

Within the confines of the district, and on lands draining to the contiguous waters, resides a population which, in 1905, reached 5,332,186. The principal centers of settlement were concentrated around New York harbor and Newark bay. The New York State part, with a population in 1905 of 4,128,799, includes the whole of the City of New York, together with additional territory lying north of the Bronx and stretching out along Long Island Sound beyond New Rochelle and embracing the valley of the Bronx and the city of Yonkers. The New Jersey part, with a population in 1905 of 1,203,389, comprises the lower portions of the valleys of the Hackensack, Passaic and Rahway rivers, together with the territory tributary to the Hudson river from the west below Mt. St. Vincent. It includes, at the northern limit of the metropolitan district, the city of Paterson in the Passaic valley and Hackensack and Englewood in the Hackensack valley.

Within the limits of the district are represented practically all types of industry, manufacture, commerce and occupation prevailing in this latitude, as well as residential sections of all classes, including tenement districts, cheap, moderate and high class residential sections, suburban villages and spacious estates. The population is cosmopolitan, there being large districts where different nationalities congregate and follow the customs of their native lands. Nearly every known language is represented by colonies sometimes of considerable size, and the habits of their denizens are as various as the different nationalities represented.

The relative density of population of the different sections varies from less than 150 persons per square mile in rural districts to more than 200,000 per square mile in the densely settled sections of the east side of Manhattan. Averages for the different portions follow:

RELATIVE DENSITY OF POPULATION IN THE CITY OF NEW YORK

Borough of Manhattan	90,000 per square mile
Borough of Brooklyn	19,300 per square mile
Borough of Bronx	5,300 per square mile
Borough of Richmond	1,400 per square mile
Borough of Queens	1,230 per square mile

RELATIVE DENSITY OF POPULATION IN NEW JERSEY

In the Passaic valley	5,800 persons per square mile
In the Joint outlet sewer district.....	1,700 persons per square mile
In the Rahway river territory.....	253 persons per square mile

PRINCIPAL INDUSTRIES

In New York the southerly third of Manhattan is, with the exception of a portion of the tenement district on the east side, given up to business and commercial pursuits. Above Thirty-fourth street, from the Hudson river to about Third avenue and extending nearly to the Harlem river the territory is essentially residential. The principal manufacturing district is on the east side of Manhattan bordering along the East and Harlem rivers.

Of the 30 miles of waterfront of Manhattan at least 17 miles, comprising the whole of that along the East river, a portion of that along the Harlem river, and of that of the Hudson river as far up as Eightieth street, is devoted to the interests of navigation and freight.

The lower end of Manhattan, particularly the financial district, has during the day a very large, and during the night a small population, owing to the establishment there in recent years of many tall office buildings.

In Brooklyn the manufacturing and maritime business is largely confined to the waterfront on the Upper bay and East river between the Erie basin on the south and Newtown creek on the north. The district devoted exclusively to business is small as compared with that of Manhattan, the residential section, on the other hand, being very much greater in area than that of Manhattan; Brooklyn is essentially a city of homes, and with the improvement of rapid transit facilities in recent years has extended almost to the sea by the absorption of a large portion of the territory south

of Prospect Park, which only a few years ago was extensively devoted to small farming and truck gardening.

The Bronx, like Brooklyn, is essentially a residence section; its manufacturing and maritime interests are centered near the confluence of the Harlem and East rivers.

In the Borough of Queens, outside of the manufacturing enterprises at Long Island City, Ravenswood, Astoria and Steinway, the settlement is largely commercial and residential, yet there is still a considerable area devoted to agriculture.

In the Borough of Richmond the manufacturing and maritime interests are centered along the waterfront at the northern end of the borough, the remainder of the territory being devoted to residential and agricultural purposes.

Of the interests in the New Jersey district those of Paterson, Passaic, Newark, Jersey City, Hoboken and Bayonne are largely manufacturing; the balance of the New Jersey territory is occupied by residences and small farms.

The chief industries of the metropolitan district are manufacturing, commercial and agricultural, the agricultural interests being largely confined to the raising of garden truck. Among the leading articles of manufacture in The City of New York are: clothing, \$228,008,835; refined sugar, \$88,598,113; books and periodicals, \$77,882,237; foundry products, \$41,089,574, and manufactured tobacco, \$37,998,261. This latter figure exceeds the bread and bakery products which amounted to \$32,239,307. These statistics are for the year 1900. In the New Jersey district Paterson is the leading silk manufacturing city in the United States, the value of the product in 1900 being \$26,000,000. Bayonne is a center for petroleum refining, the value of the product in 1900 being \$28,861,000. At Newark the principal industries are the manufacture of jewelry and leather goods, while at Passaic is situated one of the largest woolen mills in the world.

GRADUAL AND INCREASING POLLUTION OF THE HARBOR

The growth of this enormous population, with its manufactories, markets and industries along the borders of the harbor, has gradually resulted in polluting the harbor water sufficiently to attract public notice.

The situation is not unique nor exceptional. Large centers of population in other parts of the world have had similar histories, and many have been forced to find remedies. London has her main drainage works; Chicago has diverted her sewage from Lake Michigan to the Mississippi river through an artificial channel of size comparable with a ship canal; Marseilles takes her sewage to the sea through a large tunnel; the City of Mexico has extensive works to conduct her sewage and drainage away from centers of population; Boston has her metropolitan main drainage works to abate nuisances in her harbor and inland waters; Baltimore is

building extensive works for sewage purification; and Hamburg, Glasgow, Dublin and Belfast have elaborate systems to secure the satisfactory disposal of their sewage. Numerous other cities in both hemispheres have undergone the experience which the cities around New York harbor are now facing.

Owing to the difference in the sizes of the various populous communities in the New York district and to the nature and volume of flow of the different water courses receiving their wastes the extent to which the waters are polluted varies in degree with each locality.

Some of the waters, as for instance the Passaic river in New Jersey, Newtown creek and Gowanus canal in Brooklyn, as well as the Harlem river and parts of the East river are now so badly polluted as to constitute public nuisances against which a popular outcry has been directed for a long time.

Some sections of this district not immediately centered on the tidal waters have taken joint action to improve the conditions. These sections have been the first to see the necessity for action owing to the relatively intense pollution of their small local water courses, and have come to the belief that joint action of the several communities suffering from each other's putrescent wastes would be more effectual than single-handed efforts by each. The Passaic Valley Sewerage Commission and the Bronx Valley Sewerage Commission, and the Commission for the Joint Outlet at Bayway, are the outgrowth of such conditions in their respective territories.

Other localities, such as exist on Long Island and the Bronx, have had to solve their difficulties. Among these are Jamaica, Far Rockaway, Elmhurst, Coney Island, Sheepshead Bay, East New York, New Rochelle, Mt. Vernon and White Plains. These places have established local plants for dealing with their sewage. Still others, as for example East Orange and Summit, have small local and antiquated disposal plants which have been abandoned to join with other communities for simpler and more satisfactory means of removing the sources of trouble.

The more important communities which lie about the larger bodies of water, such as the five boroughs of New York, Newark and Jersey City, have heretofore given little thought to the question of the ultimate disposal of their sewage except in the manner practiced since the earliest times; that of dumping it into the harbors and rivers. The larger communities, however, are now approaching the time when their local waters are becoming overpolluted just as the smaller districts above mentioned reached this situation some years ago.

For a more comprehensive statement of the sewerage works of the municipalities in the district and their relation to the harbor waters reference should be made to the descriptions of these works in Chapter V, Part III, of this report.

SECTION II

FEASIBLE METHODS OF DISPOSING OF SEWAGE

The act under which the Metropolitan Sewerage Commission was appointed asks what methods of collecting and disposing of the sewage and other wastes which pollute or may eventually pollute the waters contemplated in this act are most worthy of consideration.

The first necessity is for better sewerage and better methods of sewage disposal than exist at the present time. As far as practicable, the sewers should be so built as to permit of continuous and uninterrupted flow and not be, as too frequently happens now, tide-locked and flooded with harbor water during the greater part of the time.

Collection Systems. The sewage should be collected by sewerage systems which will promptly remove, without stagnation or interruption, the wastes from their points of origin to suitable points for final disposition. The points for disposition should be as numerous, and be located in as many parts of the metropolitan district as efficiency, convenience and economy require. The requirements to be met in the various parts of the metropolitan district differ materially. The method of disposal for each situation should be carefully adapted to the circumstances surrounding that situation. The method need not, and should not, be the same in all cases.

Disposal Through Dilution. Much of the sewage which under ordinary circumstances would flow into the harbor should be kept out of it, and the sewage which it is not feasible to dispose of otherwise must be emptied into it in such condition and under such circumstances as will provide satisfactory assimilation with the harbor water and the best chance for seaward carriage.

Methods of Partial Purification. Among the practical methods which are available for removing impurities from sewage so that the residue can be discharged into the harbor waters without injury to the public welfare, are grit chambers, settling basins, precipitation tanks, screens and filters.

Grit Chambers. Grit chambers are necessary as a preliminary to pumping sewage and are usually employed as a first step in purifying sewage by any process. Their function is to remove sand and other heavy solid particles which easily and quickly settle when, for some reason, the velocity of the sewage current is checked. Sewage is usually passed rapidly through grit chambers.

Settling Basins. Settling basins are larger than grit chambers. Their function is to permit solids less heavy than grit to subside while the sewage passes through. Sewage is usually allowed to take several hours in passing through a settling basin.

Precipitating Tanks. A precipitating tank is essentially a settling tank in which the deposit of solids is accelerated by the use of chemicals.

Screens. Screens are used to remove floating solid matters from sewage. They are of great diversity of form, but may be divided into two general classes, coarse and fine, depending upon the size of the openings. Coarse screens, with openings of half an inch, or so, are used to intercept large particles such as fragments of garbage, rags, sticks and cloth. Like grit chambers, they are usually employed to protect pump valves when sewage is pumped. Fine screens sometimes have openings of less than one-tenth inch. Screens are often of ingenious design and are capable of materially improving sewage.

Filters. Filters for sewage are of various kinds. They are capable of removing solids from sewage, but they are most useful and most often used to oxidize dissolved organic matters where a high degree of purification is demanded.

Irrigation. Under some circumstances sewage can be utilized for the cultivation of crops, but the land in the vicinity of New York is not generally suitable for this purpose, and the expense of pumping to distant points would be very large.

Sea Disposal. Owing to engineering difficulties and the great cost involved the collection to a central station and the dumping of all the sewage of the metropolitan district at sea would be impracticable.

Slight Manurial Value of Sewage. Contrary to general belief, the manurial ingredients of sewage cannot be recovered so as materially to reduce the expense of handling it. Theoretically the manurial value of sewage amounts to \$1 to \$1.25 per capita per year, but there seems to be no city in the world which is handling its sewage at a profit. It is true that some large cities, notably Paris and Berlin, utilize their sewage by irrigating farm land, but this requires large areas of territory and is practicable only where the soil is suitable, the land cheap, the sewage useful for the water which it contains, and where a ready market for the irrigated crops exists. The conditions about The City of New York are unsuited for the profitable exploitation of such a project. A part of the manurial ingredients of sewage can be extracted by passing the sewage through tanks in which the solid particles will settle out with or without the aid of chemicals. But this process requires the handling of large volumes of a bulky sludge, containing 90 to 95 per cent. of water. This sludge cannot be utilized without drying or pressing, and these procedures are expensive. If the present quantity of sewage produced by New York was to be treated by precipitation with chem-

icals it is estimated that about 14,000 tons of sludge would be produced each day. The cost of disposing of this sludge would be large, yet the technical difficulties in the way of handling it would not be insurmountable; it could be shipped to sea, for instance.

Bacterial Processes. Various so-called bacterial processes of purifying sewage have been developed in the last ten years. Their object is to dispose of the impurities in a harmless and inoffensive manner and with the least expenditure of time and money. Some of these bacterial processes are of much scientific and practical interest. They are particularly useful where a high degree of purification is desired.

Fine Screening. If sewage is screened and passed through suitably constructed settling tanks, the visible particles may nearly all be removed. Screens have been brought to a high state of perfection in Europe, where they have been employed to remove particles as small as one-twenty-fifth of an inch.

Grease Removal. Grease may be removed in connection with screening. Screening, settling and the removing of grease are extensively practiced in Germany as a suitable procedure preliminary to discharging sewage into rivers which are not used for drinking purposes and where the proportion of sewage to river water is small. The cost of this treatment is not great as compared with the cost of the more refined bacterial processes.

Land Required. It is to be remembered that all methods for the purification of sewage require works which must occupy land, and that land is expensive in the metropolitan district. Grit removing, screening, settling and precipitating take less land than other processes. Sewage farming takes the most land.

Works for purifying sewage are becoming increasingly common for inland cities, and there are many cities in Europe and America which have found it necessary to protect their harbors in this way against pollution.

Protection of Harbors Abroad. London partly purifies its sewage with chemicals and ships to sea 7,500 tons of resultant sludge per day. The city of Glasgow treats its sewage in the same way as does London. Dublin, Belfast, Hamburg, Marseilles and Amsterdam all protect their harbors by public works which have cost large sums of money.

Harbor Protection in the United States. In the United States the city of Boston and many municipalities in its vicinity have built sewerage systems which carry their sewage far out into the harbor. The city of Providence, Rhode Island, purifies its sewage after the London principle. Baltimore, the latest large American seaport to devise a comprehensive sewerage system, has adopted a plan of sewage purification including sedimentation and filtration.

New York is the largest seaport which has no definite plan or policy with respect to sewage disposal.

Extent of Existing Purification Works. Of the 26 cities of Europe and America which have populations of over 500,000 about one-half purify their sewage or follow some other carefully devised plan for disposing of it. Of the nine cities of over 1,000,000 inhabitants three purify their sewerage, one carries it away a long distance by an especially built canal, and the remainder discharge it into great bodies of water without any plan or concern as to its ultimate fate. Statistics are not available to show how large is the aggregate sum of money invested in all the sewage disposal plants which exist in various parts of the world, but some idea of the number and extent of these undertakings can be had from the fact that works are now in operation which purify the sewage of not less than 18,000,000 people.

SECTION III

FEASIBILITY OF ADOPTING A GENERAL PLAN FOR PROTECTING THE HARBOR WATERS FROM POLLUTION

The second paragraph of the Act which provided for the creation of the Metropolitan Sewerage Commission specifies, as one of the duties of this Commission, the consideration and investigation of the most effective and feasible means of permanently improving and protecting the purity of the waters of New York bay and neighboring waters, giving attention particularly to the desirability and feasibility of The City of New York and the municipalities in its vicinity agreeing upon a general plan or policy of sewerage and sewage disposal which will protect the waters of New York bay and vicinity against unnecessary and injurious pollution by sewage and other wastes.

Desirability of Interstate Agreement. A careful consideration of the sewage disposal problem of the metropolitan district leads to the opinion that the sewage of The City of New York and the municipalities in its vicinity should, for a perfect solution of the problem, be dealt with in accordance with a general policy which should be made the subject of agreement between the two States of New York and New Jersey.

The middle of the harbor is the dividing line between the States of New York and New Jersey, and unless an agreement can be entered into the waters in their entirety can not be protected as effectively as would be desirable, there being no single interested authority having jurisdiction over its sanitary condition.

In the absence of control by a central body or by either State, the cities of the

two States may be expected to go on as now, each adding to the defilement to the mutual injury of the other until drastic measures are necessary to relieve the waters of their offensive condition.

Future Conditions. The present condition of the harbor and the rapidly increasing quantities of sewage which are being discharged into it make it evident that the time is approaching when the two States will be compelled to place the protection of the harbor against sewage in the hands of a single authority as they have been forced to arrange for the management of quarantine by New York State and the disposal of solid refuse by the United States Government.

Quarantine Regulations Under Interstate Agreement. In early times questions of quarantine were continually arising between the States of New York and New Jersey, each State asserting its sovereignty over its part of the waters, to mutual inconvenience and injury of public health and welfare. This led the two States in 1832 to form an agreement whereby the State of New York took charge of the quarantine and police regulation of the harbor to the New Jersey shores.

Dumping of Garbage Into Harbor Stopped. Until recent years, New York harbor was considered to be a suitable place for the dumping of all the garbage and other refuse which was produced by the cities and towns in its vicinity. In the course of time the dumping of solid matters into the harbor had to be given up and a form of police jurisdiction was established by the United States Government to keep solid refuse out of these waters. The justification of the general government for taking control of this matter lay in the belief that injury was being done to the navigable channels.

Community of Interests Should Secure Unity of Action. The community of interests which exists among the people of the States should lead to a common effort to protect the harbor against unnecessary and injurious defilement. It will be regrettable and expensive, not to say dangerous, if the existence of State boundary lines is to prevent the centralization of sanitary authority where public health is concerned.

Plan for Conservancy by New York in the Absence of a General Plan for the Whole District. Until such time as a general plan of conservancy can be agreed upon between New York and New Jersey The City of New York should, for her own protection, and in the interests of economy and public health, proceed to formulate a general plan to which future sewerage and sewage disposal works in the New York territory should be adapted. There is much to be done to improve conditions which are local in New York, to provide for a proper development and extension of the existing sewerage systems and to protect and improve those parts of the harbor which lie completely within the limits of New York State.

SECTION IV

FEASIBLE METHODS OF ADMINISTRATIVE CONTROL FOR A METROPOLITAN SEWERAGE DISTRICT

The legislative Acts which provided for the creation of the Metropolitan Sewerage Commission of New York finally ask what would be the best system of administrative control for the inception, execution and operation of a plan for sewerage and sewage disposal of the metropolitan sewerage district; whether by the action of already existing departments and provisions of government; by the establishment of separate and distinct sewerage districts and permanent commissions in each State; by the creation of one interstate metropolitan district and commission to be established by agreement between the two States, this agreement, if necessary, to be ratified by Congress; or whether by other means.

The only governmental authority which is common to the two States of New York and New Jersey is the United States Government, and this has not attempted to specify the method or supervise the construction of works for the discharge of sewage into State or interstate waters.

Existing departments of government in the States of New York and New Jersey would be prevented from uniting to devise and execute a plan of sewerage and sewage disposal for the metropolitan district, for the reason that in New York such questions are left to the State Department of Health and that Department does not attempt to exercise jurisdiction within the limits of The City of New York.

Where questions affecting public comfort and well being are so largely concerned some other form of jurisdiction is more appropriate than that of a public health department.

Royal Commission on Sewage Disposal of Great Britain. The main authority which is responsible for the sanitary protection of the river Thames is not a public health body. The Royal Commissions on Sewage Disposal of Great Britain, with one exception, have not been health boards, nor have the various Rivers Boards of England, which are doing good work for the sanitary protection of water courses.

The last report of the (temporary) British Royal Commission on Sewage Disposal recommends the creation of a permanent central sewage authority which shall carry on suitable investigations and be ready to give expert advice to local authorities as to methods for the sanitary disposition of sewage and act as a court of last resort

in all matters of dispute concerning the disposal of sewage in the several localities of England.

German Imperial Board of Health. In Germany the Imperial Board of Health exercises jurisdiction over streams only in so far as health is surely and directly concerned. The sanitary improvement and protection of the rivers so far as they may be maintained in a condition suitable for the business and enjoyment of the public devolves upon other authorities.

Special Commissions. In America, where there is no central health authority, the protection of the water courses is left to the care of the individual States. Some States require that all plans for sewerage, as well as sewage purification, shall be passed upon by the State Board of Health before they are carried out. American harbors are protected, where any protection exists, chiefly through works constructed by sanitary authorities such as sewerage commissions, which have no jurisdiction over other matters of public health. The need and nature of such work are often determined by a special board of commissioners. This has been true of Boston and Baltimore.

Intercity Agreements Impracticable. The remaining form of co-operation which remains to be considered between existing forms or departments of government, would be one reached through an agreement between the several municipalities concerned. When the multiplicity of places is considered (there are 189 municipalities in the metropolitan district) the impracticability of forming and maintaining a cohesive and useful co-operation among them becomes manifest.

Commission for New York State Recommended. The two States can not be expected to co-operate in this work at once but may be expected to do so later. Therefore a commission should be created for New York State, with instructions to co-operate with New Jersey, if possible, to the end that an adequate settlement of the problems of sewage disposal can be secured.

Duties of Proposed Commission. This central board should propose, but not necessarily build, such works of main drainage as are required to permanently improve and protect the purity of the water of New York bay and neighboring waters. The commission should not be charged with the duty of executing local sewerage works but should have advisory authority over their design at least in so far as they would relate to the general plan for main drainage. The sewers needed for purely local purposes should be designed by the several municipalities. The central board should be required to examine and pass judgment upon all new projects for sewerage within the territory under their jurisdiction when requested to do so by the local authorities having these projects in hand.

The commission should have power to employ such technical and other assistants as would be required for the work, and fix their salaries, and should be authorized to purchase supplies and do all other necessary things for the execution of the work for which it is created.

Appointment of Commission. The commission, so far as it represents the State of New York, should be appointed by the Mayor of New York in accordance with a special Act of the Legislature and should report to him.

CHAPTER II

DIGEST OF COMMISSION'S INVESTIGATIONS

SECTION I

BRIEF SUMMARY OF THE WORK ACCOMPLISHED BY THE METROPOLITAN SEWERAGE COMMISSION

Meetings. The Commission has held regular weekly and many special meetings at which all the Commissioners have usually been present. Up to April 30, 1910, the Commission, since it was reconstituted, has held 120 meetings, at which all phases of the Commission's investigations have been planned and discussed. Routine and special reports from the employees have been presented at the meetings and all expenditures have been authorized, and bills audited.

Collection of Data. The detailed work of collecting data has been done partly by the members of the Commission and partly by employees under the immediate direction of the president who has acted as the presiding officer of the Commission and as the executive head of the board.

Study Trips. The Commissioners have made numerous trips, by land and water, through the metropolitan district to study the conditions attending the discharge of sewage and obtain information concerning the topography, distribution of population and other facts necessary to form an intelligent opinion as to future requirements of sewerage and sewage disposal.

A trip was taken by the Commissioners to Boston and the sewerage and sewage disposal works of that city and of the metropolitan district of Boston, including about 25 cities and towns were studied.

Exhibition. At the request of the Mayor, an exhibit of the main features of the Commission's work was held in connection with a public exhibit on congestion of population and town planning at the Twenty-second Regiment Armory in May, 1909. The Commission's exhibit consisted of maps, charts, diagrams and photographs prepared to show the present conditions and consequences attending the discharge of sewage into the harbor and the ways in which other, both American and foreign, cities have protected their harbors against pollution. The exhibit occupied a wall space of 560 square feet and was viewed by about 200,000 people.

Hearing on Passaic Valley Sewer Before Harbor Line Board. At a hearing before the United States Harbor Line Board held to collect information concerning the

possible effects which the discharge of the proposed Passaic valley sewer at Robbins Reef might have upon the depth of water in the navigable channels of the harbor, the Metropolitan Sewerage Commission, at the request of the Mayor, presented a brief statement of its views on the project.

The district over which the Commissioners' investigations have extended has covered metropolitan New Jersey as well as metropolitan New York. About the same extent of territory has been included in each State.

Invitation to New Jersey to Co-operate. Although the investigations have covered conditions in New Jersey, the Commission has had no official co-operation from that State. The State of New York by letters addressed by the Secretary of State to the Governor of New Jersey twice invited the State of New Jersey to co-operate in the Metropolitan Commission's investigations, but without result. The last invitation extended at the request of the Metropolitan Commission was dated November 12, 1908.

Co-operation of Other Departments of The City of New York. Co-operation by the permanent departments of the government of The City of New York has contributed materially to the success of the Commission's work. The Commissioner of Docks set aside an unused space on Pier A at the mouth of the Hudson river, where the Commission established a laboratory. The New York Zoological Society through the Director of the Aquarium at the Battery permitted experiments to be made from time to time in tanks of harbor water and sea water on a scale and under conditions which it would have been difficult to obtain elsewhere. The Department of Health and the Department of Water Supply, Gas and Electricity and the Board of Water Supply of The City of New York furnished useful data of several kinds. The Bureau of Sewers of the Department of Public Works for Manhattan, as well as the Bureaus of Sewers in the other boroughs, have given information which has been of material help. The sewer authorities throughout the metropolitan district have facilitated the Commission's studies of their several sewerage systems.

Co-operation of United States Coast and Geodetic Survey. Assistance in studying the tidal phenomena of the harbor was received from the United States Coast and Geodetic Survey, as a result of a visit which members of the Metropolitan Commission made to the Department of Commerce and Labor to request the co-operation of the United States Government in its work. At the request of this Commission, an exhaustive research and report were made by the officials of the United States Coast and Geodetic Survey covering an examination of reports, documents and unpublished records in their official archives to determine with the greatest practicable accuracy the quantities of water flowing in and out of the harbor, the direction and force of the currents, and other facts.

Assistance from Many Sources. A large number of engineers in official and private life in New York and in other cities contributed information which has been of value in preparing this report. To all who have helped in this way full acknowledgment is here made of the assistance received and the thanks of the Commission are extended.

Investigations. Investigations of the conditions of the waters have been a prominent feature of the Commission's work. In general, their object has been, (a) to show the extent to which the waters were polluted, and (b) to study the circumstances under which the waters could be utilized in disposing of sewage in future in case further investigation showed that it would be too expensive to keep all sewage out of the water.

Digest of Early Data. Before undertaking new examinations of the water, efforts were made to obtain every analysis of consequence which had been made of the waters of the harbor prior to the reorganization of the Commission. A careful review and digest of data concerning the quality of New York harbor waters prior to January, 1908, was published by the Commission in August, 1909. This investigation was supplemented by further analyses after the need of additional information became apparent.

Analytical Work. The analytical work has been done in the Commission's own laboratory by assistants of recognized skill in this kind of work. From time to time the services of well known consulting experts have been employed to advise with respect to various phases of the investigations.

Laboratory. The laboratory has been located on Pier A, which is situated at the mouth of the Hudson river near the centre of the metropolitan district. The samples for analysis have been collected by means of boats chartered by the Commission. One of these boats was fitted up as a floating laboratory for analyses which it was desirable to make as soon after collection as possible.

Volume of Analytical Work. The Commission since its first organization has made, roundly, 4,000 chemical or physical analyses of the water of New York harbor and 2,000 bacteriological examinations of these waters. These figures include analyses of deposits found upon the harbor bottom. Of the total number of analyses 1,135 have been made since March 3, 1909 for bacteria in the water. There have been 844 determinations of the amount of dissolved oxygen in the water to measure the effects of the existing pollution. Deposits from the harbor bottom have been analyzed microscopically to the number of 806 samples. In addition, continuous tests of the salinity of the water have been made for the entire year 1909 at all stations situated in different parts of the harbor.

Special Investigations. Beside the analytical work, a number of special investigations have been made bearing on (a) the present and probable future sanitary condition of the water, and (b) the capacity of the harbor for harmlessly and inoffensively absorbing sewage. Among these investigations, the following may be mentioned:

Existing Sewerage Works. Study of the present sewerage conditions in the several boroughs of New York and of the other cities and municipalities within 20 miles of New York City Hall.

Inspection of the Sewer System of Manhattan. With the co-operation of the Borough President and Chief Engineer of the Department of Sewers, the sewers of Manhattan were inspected by the employees of this Commission to ascertain their general condition and state of repair.

Sewer Outlets. Determination of the location, size and volumes of discharge of the principal sewer outlets in the metropolitan district.

Street Refuse Entering Harbor. Estimates of the quantities of refuse which enter the harbor from the streets of the principal cities bordering upon the harbor.

Population Estimates. Estimates of future population for every five years until 1940, including a review of estimates by other authorities.

Future Sewerage Needs. Inspections of the harbor and of the outlying districts with respect to future needs of sewerage and sewage disposal.

Pollution of Beaches and Bathing Establishments. Experiments to determine the extent to which bathing places are polluted by sewage.

Transportation of Sewage by Currents. Experiments to determine the extent of transportation of sewage by the tidal currents of the harbor.

Diffusion and Digestion. Experimental studies to show the possibilities of diffusing and dispersing sewage matters through the waters of the harbor.

Tidal Phenomena. Theoretical study of the principal tidal phenomena of New York harbor supplementary to a report by the United States Coast and Geodetic Survey.

Float Studies. Practical study of tidal phenomena as shown by the course taken by specially constructed floats.

Typhoid Outbreak. Investigation into the cause of an outbreak of typhoid fever at Bath Beach.

Digestion of Sewage Solids. Experiments on the digestion of sewage solids in the harbor water.

The details of these and other studies will be found in the various chapters of Part III of this Report.

SECTION II

FLOW OF TIDAL WATER

Net Discharge Seaward Through the Narrows. The volume of water discharged seaward through the Narrows in excess of the volume which returns is about 15 per cent. of the total movement in either direction. It is 1,750 million cubic feet each tide under usual conditions, and 950 million cubic feet under conditions unfavorable to a large net outflow.

Total Flow Through the Narrows in Both Directions. During average conditions the total volume of water which flows in either direction through the Narrows is 12,540 million cubic feet on ebb tides and 10,790 million cubic feet on flood tides. Under conditions unfavorable to a large ebb outflow the quantities are 6,775 million cubic feet during each ebb and 5,825 million cubic feet during each flood tide.

Net Flow Seaward of Hudson and East Rivers and Kill van Kull. The average net ebb flow from the Hudson at each tide is 1,170 million cubic feet. From the East river it is 450 million cubic feet. From the Kill van Kull it is 78 million cubic feet.

Velocities of Tidal Flows. The tides run most swiftly in the East river. The strongest currents in the East river attain a velocity of two to four knots per hour. The currents in the Hudson usually range between two and three knots per hour, and the velocities at the Narrows usually range between 1.5 and two knots per hour. These rates represent the speed of the currents after they have attained practically their full velocity and are not averages made by dividing the total movement of water in one direction by the period of time that the water flows in that direction. For about two-thirds of the time the current is slacking, reversing and regaining its ordinary velocity.

Ranges of Tide. The rise and fall of tide varies in different parts of the harbor. At Governors Island in Upper New York bay the mean is 4.4 feet. At Sandy Hook the usual range is 4.7. At Throgs Neck, 7.2.

Effects of Winds on Tides. The range in Upper New York bay is not uncommonly increased or diminished to the extent of 50 per cent. by the wind.

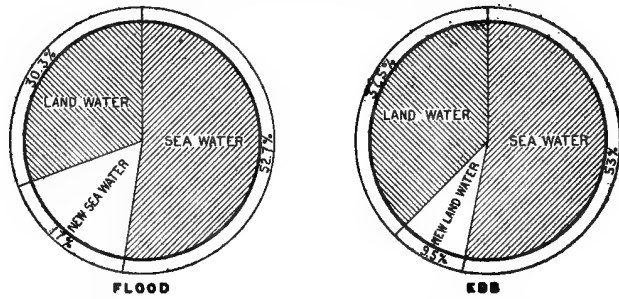
Salinity of Harbor Waters. The water of New York harbor is composed of a mixture of sea water and land water in constantly varying proportions. The following ratios will give an idea of the composition as indicated by approximately average figures covering one year's continuous observations:

East river, east end—20 per cent. land water and 80 per cent. sea water.

East river, midway between ends—40 per cent. land water.

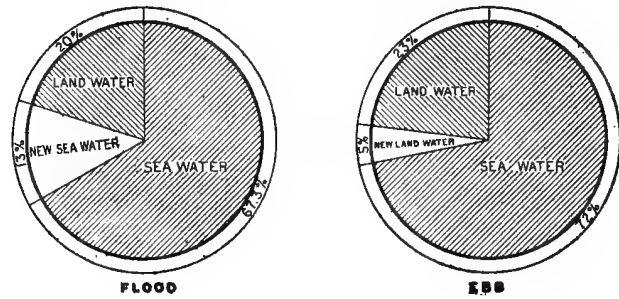
SUMMARY OF INVESTIGATIONS

AVERAGE CONDITIONS



DRY WEATHER

CONDITIONS



PROPORTIONS
OF
LAND WATER AND SEA WATER
AT
THE NARROWS

East river, south end—48 per cent. land water.

The Hudson contains 75 per cent. of land water at Tarrytown and 40 per cent. of land water at its mouth. Upper New York bay and the Raritan bay contain about 25 per cent. land water. At the outer limits of New York harbor, that is, at Ambrose Light Vessel, the water usually contains about 10 per cent. of land water and 90 per cent. sea water.

Imperfect Conditions for Assimilation. The quantity of water which flows in and out of New York harbor, although large, is not a measure of the capacity of the harbor to transport or assimilate sewage. The idea of transportation involves the assumption that the matters which are carried away are not brought back again. The oscillation of the tide carries the sewage back and forth indefinitely. The idea of assimilation involves the assumption that the sewage becomes so mingled with the water as properly to be considered part of it. Again, investigation shows that this condition is not always fulfilled.

The movement of the tides produces a refreshing effect upon the harbor but this benefit is restricted because (a) tidal action is usually least in those places which need it most, (b) thorough mixture of the sewage with the water does not always occur promptly, (c) the currents are intermittent, and not continuous, as are those of a river flowing in one direction, (d) the action of the tidal currents carries some sewage matters on the surface and some toward shore, (e) the force and direction of the tidal currents are materially influenced by the wind (f) excepting near the sea and sound entrances the same water flows back and forth and is not pure sea water by any means.

Oscillatory Movement of Harbor Waters. Contrary to popular belief, the movement of river and tidal water to sea does not proceed in a regular and reliable manner. Studies of the course followed by objects so constructed as to float just below the surface of the harbor have shown that the water oscillates back and forth, sometimes to an indefinite extent, before escaping to sea.

In the more open parts of the Hudson river and Upper and Lower New York bays there is a generally northward and southward oscillation, the southward movement being in excess.

The waters which pass out of the harbor by way of the Narrows go to sea, for the most part, by the northerly channels of the Lower bay.

The water of Newark bay oscillates between the head of the bay and the eastern end of the Kill van Kull, eventually escaping chiefly to New York bay and so to the ocean.

The water flows more rapidly in the East river than in any other arm of the harbor, but most of the water moves back and forth, like the pendulum of a clock, without escaping to the ocean or to Long Island Sound. A buoy which was made to float, except for a small tell tale, just below the surface of the water, was followed back and forth for three and a half days in the East river. At the end of this time it had traveled 108 miles without passing out of this stream. It returned several times to the locality where it had been set adrift.

SECTION III

POPULATION AND SEWAGE

Population. The total population in the metropolitan district in 1905 was 5,332,000. It will probably be at least doubled by 1940, as will the population of The City of New York, which in 1905 was approximately 4,000,000.

Outside of The City of New York in the metropolitan district of New York State the population in 1905 was 128,000. The rural districts of metropolitan New Jersey had more than twice this population, or 293,000.

There were ten cities in metropolitan New Jersey which had populations of over 25,000 in 1905. The largest of these were Newark and Jersey City, each of which had a population exceeding 230,000. The total population of these ten cities was 910,000 in 1905, and will probably be at least 1,700,000 by 1940.

The sewage produced in the metropolitan district is discharged into the harbor either (a) directly, near open navigable channels, as is the case with New York, Yonkers, Jersey City, Hoboken, Bayonne and Elizabeth or (b) indirectly into these channels by way of the rivers, as is the case with White Plains, Mt. Vernon, Paterson and Passaic.

Quantities of Sewage Discharged into the Harbor. The total quantities of sewage discharged into New York harbor per day at the present time are approximately as follows: Into the East and Harlem rivers 335,600,000 gallons, into the Hudson river 164,200,000 gallons, into Upper New York bay 104,100,000 gallons.

Points of Discharge. The sewers discharge at or near the shore line at mean low water. The point of discharge for the sewers has been selected in practically each case with the object of getting rid of the sewage at the least cost for sewers and with little or no consideration of the consequences to the public welfare through a contamination of the water into which the sewage is emptied.

Want of care in protecting the purity of the streams has produced intolerable conditions in some parts of the metropolitan district and to remedy these, trunk

sewers have been built or are projected to carry the sewage to more open parts of the harbor.

Purification Works. In a few cases works to purify the sewage have been built, but for the most part these plants have not been designed or operated in accordance with good engineering or economic principles and the results are generally unsatisfactory.

Extension of Outfalls. The usual plan followed to abate nuisances which have occurred from the discharge of sewage into tributaries of the harbor is to carry the sewage to some other point for disposal. This has generally been done by building the sewer further out toward the more open waters of the harbor.

Joint Outlet Sewer. A number of towns in the Counties of Essex and Union in New Jersey have constructed the Joint outlet sewer, which empties its contents into the Arthur Kill near the south end of Newark bay. The territory included by this drainage system is 37 square miles. The ultimate population provided for is 150,000 and the quantity of sewage which can be accommodated is 21,000,000 gallons per day.

Bronx Valley Sewer. A trunk sewer is being built to carry the sewage which now flows into the Bronx river in New York State from White Plains to the New York city line to the Hudson river at Mt. St. Vincent. The territory drained will be 34.8 square miles. The present population is 32,700, and the ultimate quantity of sewage provided for is 90,000,000 gallons per day.

Passaic Valley Sewer. It is proposed by citizens of New Jersey to relieve the Passaic river of the sewage which flows into it by constructing a trunk sewer which will run from Paterson to the middle of Upper New York bay. The territory to be included in this project is 103 square miles. The ultimate population to be provided for is 1,650,000, and the quantity of sewage 630,000,000 gallons per day.

Effects on the Harbor. The effects upon the harbor which trunk sewer projects may produce cannot all be foretold with accuracy, although some of the principal consequences may be anticipated. It is certain that the transfer of many million gallons of crude sewage from inland places to points nearer the centre of the harbor cannot take place without injury to the latter.

The measure of improvement to the locality benefited and the injury to the harbor will depend upon the completeness with which the sewage is transferred from the one place to the other. The risk is twofold. First, there is the chance that the sewage will produce a nuisance before it becomes thoroughly mixed with the water, and, Second, there is risk that the sewage, after mixing, will overburden the capacity of the water to digest it.

General Plan for Conservancy Needed. Within the metropolitan district conditions of sewerage and sewage disposal now require, and always will demand, unusually careful and skillful management if the evil consequences of sewage pollution are to be prevented. The topographical, residential and industrial conditions in this territory are varied in the extreme. For many of the municipalities what may be termed natural facilities for sewage disposal are wholly lacking; for others opportunities which once existed have been taken away by the growth of neighboring municipalities. For practically all the cities and towns in the metropolitan district the problem of disposing of sewage without danger or offense has become impossible to solve as a local question.

Sewage in crude form is discharged scarcely anywhere on land or in water within this area at the present time without creating a nuisance or serious risk of nuisance. If it is not a nuisance to the town which produces it it is likely to create one at some other place. Whether poured directly into a river, canal or other tributary of the harbor, or carried by a trunk sewer to the open water of the harbor for discharge, it is practically certain sometime or other to make its presence felt.

Future Pollution. It is not difficult to anticipate the result which this lack of prudence will ultimately produce if allowed to continue. If the discharge of sewage is not restricted the waters will become more and more polluted, for the quantity of sewage will increase with the population while the quantity of water into which it is discharged will remain the same.

Establishment of Plan for Conservancy. The proposal that a comprehensive system of conservancy be established by law for New York harbor is not without precedent. In fact it is the natural and usual remedy where water courses have become overburdened with sewage. It has already been successfully employed in Europe and America for the protection of rivers and harbors. The system proposed for New York harbor corresponds with that of the Rivers Boards of England and with that of the Metropolitan Sewerage Board of Boston and the 25 municipalities in its vicinity.

SECTION IV

CAPACITY OF NEW YORK HARBOR FOR SEWAGE

Self-Purification of Harbor Waters. It has been clearly shown that the sewage and other wastes which are discharged into New York harbor would create much more offensive conditions than now exist were it not that the water possesses a certain power of purifying itself. Through the action of this power a large part of the waste matters are destroyed and rendered inert before they can produce the full amount of harm of which they are capable.

There is a limit to this purifying power, or digestive capacity, as it is called. When this limit is exceeded the organic matters in the water putrefy and produce offensive odors.

Oxidation. The purifying power of the water is essentially one of oxidation. All offensive and potentially offensive organic substances, including the liquid and solid ingredients of sewage, must become oxidized to be destroyed.

Dilution. The first stage in the process of self-purification is dilution. By dilution the solids of the sewage become dispersed and the liquids diffused through the water. Without diluting the sewage there would not be enough oxygen present to permit digestion to proceed far without the production of foul gases. It could never proceed to a natural and necessary termination without an adequate supply of oxygen.

Liquefaction. The second stage in the process of self-purification consists in the liquefaction of the solids and the resolution of the liquids into stable, inert forms. These changes involve chemical combination between the organic substances of the sewage and the dissolved oxygen of the water. They take place largely through the action of living animal and vegetable organisms, chiefly bacteria.

Reduction of Dissolved Oxygen. The result of the process of self-purification is to reduce the quantity of oxygen present in solution considerably below the normal amount.

Sources of Dissolved Oxygen. The oxygen which is absorbed is replenished as it was at first derived, in part from the atmosphere and in part from the sea water and land water which enter the harbor.

The maintenance of fish life, as well as the prevention of odors from putrefaction, require that the oxygen be not too far exhausted.

Present Deficiencies. It has been shown by numerous analyses of water taken from the harbor at many places and at different depths that the sewage and other wastes which are discharged into the harbor cause a material reduction in the amount of dissolved oxygen present. The main channels of the Upper bay, Hudson river, East river and Kill van Kull contain from 60 to 75 per cent. of the oxygen which should be present.

The oxygen is entirely exhausted in the waters of the metropolitan district where pollution is greatest, as for example, in the Passaic river, Newtown creek, Gowanus and Wallabout canals and scores of docks and shipping basins.

Sewage Deposits. Sewage solids accumulate to some extent upon the harbor bottom. Practically the whole of the bottom of Upper New York bay is covered with black, ill-smelling mud in which particles of sewage origin are distinguishable. In

places these deposits have been found to attain a depth of over ten feet. In the lower bay deposits occur more often in the main channels than elsewhere.

Deposits Near Sewer Outlets. Deposits from sewers have not, apparently, caused serious shoaling in the navigable channels of the harbor, although the total quantity of solids which the combined household and storm water sewers of the metropolitan district empty into the harbor annually is very large. Filling does undoubtedly occur near outlets, and sewage solids are a conspicuous ingredient of harbor deposits wherever deposits of any kind occur. The dredging between docks and piers, which is continually necessary for the accommodation of ships along a large part of the waterfront of New York, removes black, ill-smelling mud in which sewage solids exist.

SECTION V

EFFECTS ON HEALTH

It has not been proved that the discharge of sewage into the harbor has had any appreciable effect on the general healthfulness of the metropolis or its suburbs, although it is impossible to avoid the conclusion that bathing in this water, collecting driftwood from it for fuel and eating shellfish grown in it is attended by risk of sickness.

Infection of Harbor Waters. The capacity of the water to produce disease depends chiefly upon the chance that pathogenic microbes are present and that these may in some way get from the water into the bodies of persons susceptible to the diseases of which these microbes are the product. There is no question that the sewage of New York, and consequently, mixtures of the sewage and water, are dangerous, for they contain the germs of every infectious disease which occurs there. It remains to consider how long disease germs are capable of living in the water and how the water may become a means of transference of poisonous matter to the people of the metropolitan district.

Life of Bacteria in Harbor Waters. Bacteriologists have not determined how long germs of disease are able to live in harbor water, but interesting work has been done in connection with this subject. Useful results have been obtained in studying the circumstances under which the germs of typhoid fever may persist. As far as this information goes it appears that when typhoid germs are mixed with harbor water a rapid reduction in numbers generally occurs at once. At the end of two or three days only a small percentage of the original number of bacteria are present. At the end of about a week a further slight reduction has occurred. Some survive for two or three weeks, and under exceptional circumstances it would seem that the vitality of some typhoid germs might persist for months.

Evidence is on record to show that germs of typhoid have traveled 80 miles or more in water from their point of origin before being destroyed.

There is believed to be no reduction in the virulence of typhoid germs or other microbes because of their existence in water. The most resistant survive, and these are, apparently, well qualified to multiply and produce disease in any susceptible person. It seems a well-established fact that no pathogenic microbes are capable of multiplying in harbor waters under circumstances which are likely to exist.

Methods of Acquiring Infection. The water may convey the germs of disease to susceptible persons in many ways. Chief among these are by bathing, eating shell-fish, handling driftwood and by fishing.

Obscure Relation Between Polluted Harbor and Sickness. Contrary to what might be expected, there is little statistical evidence to show how much sickness is produced by polluted harbors. Repeated attempts to collect such evidence have been made, but without success. When the river Thames at London was giving off its worst stenches, prior to the construction of the sewerage system which was built to protect the river, the vital statistics of the city showed no increase in the prevalence of any disease which the sanitarians of that day could ascribe to the odors. Inquiries indicated that the health of wharfmen and boatmen was not visibly affected. When the river Liffey was being described by British experts as the most abominable nuisance in Ireland, efforts were made to ascertain the amount of sickness near the waterfront of Dublin, but no excess of illness could be found.

Failure to discover an increase in disease does not, of course, prove that harm is not done to public health by such conditions. The methods of inquiry available are too crude to detect all the harm. Only the most conspicuous evils, such as cases of specific intestinal diseases can be hopefully looked for. The paths of infection are often too complicated to be followed. Subtle effects upon health similar to those produced by insufficient air, food, sunlight, exercise and rest, cannot readily be detected, measured and traced. It is possible that such effects may be produced by the condition of harbor waters.

Assuming it to be a fact that a polluted harbor produces no effect upon the death rate, this does not remove the necessity for keeping the water reasonably clean. The requirements of decency and order which now obtain and which will become more exacting as time proceeds are sufficient reasons for maintaining a sanitary harbor.

Nevertheless, the careless discharge of sewage into harbors does produce sickness and death, and for those who wish positive proof of this fact there is some conclusive evidence.

Shellfish and Infected Harbor Waters. The best proof of a relation between polluted harbor water and disease lies in connection with shellfish. There have been more than enough cases of typhoid fever and gastro-enteritis reliably traced to the eating of oysters, clams and other shellfish taken from polluted waters to show that a very real danger to health exists in this direction. Shellfish taken from sewage-polluted water are practically certain to be polluted.

Typhoid Fever from Oysters. In The City of New York cases of typhoid have been known to arise merely from handling the shells of oysters and clams taken from polluted places. The total amount of sickness caused by impure shellfish is not known; it is probably not great, but it is certainly more than is commonly supposed. Only the most striking and obvious cases come to light.

Within the last few years much attention has been directed to the need of regulating the sanitary conditions attending the cultivation and handling of shellfish, with the result that health authorities have been moved to abate some of the most dangerous practices. Improvements in the cultivation of shellfish have been made in the metropolitan district, but a great deal remains to be done. In most parts of the metropolitan district the shellfish industry must be given up, in others better methods of disposing of the sewage will reduce the danger. There always will be risk attending the eating of shellfish taken from the harbor. So long as shellfish grow in these waters, as they still readily do without cultivation, the public health authorities must regulate their capture and sale. There will always be some persons to gather them in spite of the best efforts of the authorities.

Bathing in Harbor Water. Bathing in the free floating bathing establishments may be refreshing and may give pleasure to the bathers, some of whom thus learn to swim; but the baths have little cleansing value. The water is unwholesome and even dangerous for bathing purposes. Floating particles of sewage enter many of the pools, even though situated 500 feet or more from a sewer outlet. When bathing it is hardly possible to avoid accidentally taking some of the water into the mouth and nasal passages and having it come in contact with the mucous membrane of the eye. It is not to be doubted that bathing in such water is a frequent source of infection.

Abolishment of Floating Bathing Establishments. As soon as possible the maintenance of free floating bathing establishments should be discontinued. This is already appreciated by the City authorities.

SECTION VI

MAIN FACTS AND OPINIONS DERIVED FROM THE INVESTIGATIONS
AS TO THE INTENSITY OF POLLUTION OF THE HARBOR WATERS

Without going into details of the technical information obtained, a full account of which will be found elsewhere, the principal facts and conclusions resulting from the Commission's work will be stated here.

Excepting Lower New York bay, the Hudson river above Spuyten Duyvil and Long Island Sound, practically all the waters within 15 miles of Manhattan Island are decidedly polluted as determined by inspections and chemical, bacterial and microscopical analyses.

In that part of the district included between the Narrows, Throgs Neck, Mt. St. Vincent and the mouth of the Raritan river the pollution is greatest.

The Harlem river is more polluted than the East river, the East river more than the Hudson and the Hudson more than the Upper bay.

In the worst places the paint on ships becomes discolored and the waters are incapable of supporting fish life. The City of New York maintains bathing establishments on the shores of Manhattan and Brooklyn in which over 2,000,000 baths are taken annually.

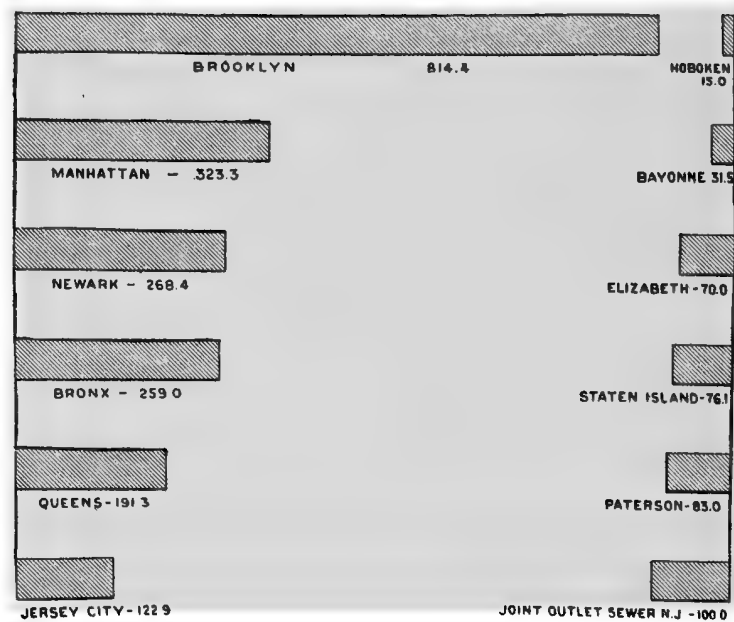
Many of the smaller rivers and inner tributaries of the harbor are now so heavily charged with sewage as to constitute extensive local nuisances. The waters in these places are black, and, in many places, effervesce with foul gases.

Outside the inner harbor, that is, below the Narrows, as well as beyond Throgs Neck and in the Hudson river above Manhattan Island, samples of water, and sediment bear evidence of pollution, although the intensity of contamination is less there than in that section which is known as the inner harbor.

Gowanus canal and Newtown creek and the Passaic river are polluted beyond the limits of toleration.

The Harlem river, particularly at its southern end, is, at times, little else than an open sewer.

SUMMARY OF INVESTIGATIONS

**MILES OF SEWERS**

CHAPTER III

SUMMARY OF EXISTING CONDITIONS WITH COMMENTS AND SUGGESTIONS

SECTION I

METHODS OF SEWERAGE IN USE

Separate and Combined Systems. The 40 cities in the metropolitan sewerage district, the sewerage of which has been described in the foregoing pages, have an aggregate population of 5,120,000 and are provided with 2,903 miles of sewers as well as 12 plants for the treatment of the sewage prior to its discharge into adjacent waters. All these cities discharge their sewage by gravity, except five in which ten pumping stations are in use to pump the whole or a part of the sewage.

There are 2,440 miles of combined sewers in 19 cities with a population of 4,603,000.

There are 463 miles of separate sewers in 26 cities with a population of 561,000.

With the exception of Paterson and Newark all the cities in the Passaic valley, within the boundaries of the metropolitan sewerage district, have separate systems of sewers, as have also the principal towns in Richmond Borough and all the municipalities in the Westchester County district outside of The Bronx. The remaining districts having separate systems are portions of those sections of the Boroughs of Brooklyn and Queens in which the sewage requires purification or treatment, and of the territory in New Jersey tributary to the Joint outlet sewer.

Relief Sewers. Owing to insufficiency in size, flatness of grades or changes in conditions since constructed many large relief sewers have been built in several localities.

In Manhattan extensive changes have been required in the sewerage system as a result of subway construction. The troubles in this regard have apparently only begun as the subways so far built keep well toward the central axis of Manhattan Island where little difficulty has been experienced in readjusting sewer grades to new conditions. When the additional subways along streets nearer the water front are undertaken much difficulty will be encountered, and a practical reconstruction of the entire sewerage system may become a necessity. The work of changing the sewers to accommodate the subways is done by the Public Service Commission. Dur-

ing 1909 this Commission built more lineal feet of sewers in Manhattan than the Bureau of Sewers, and often without consultation with the Bureau of Sewers.

In Brooklyn less difficulty has been experienced with respect to subway construction than in Manhattan, and all new sewers or extensions are planned so as to avoid interference with prospective subways. The principal difficulties in this borough have arisen from extensions of existing sewers to new territory, or the increasing of the percentage of impervious areas, such as pavements and roofs, whereby the sewers have become overcharged during heavy rains, resulting in damages of considerable extent. Examples of this are to be found in the new relief sewer emptying into the East river at Gold street, built to divert the entire flow from the old Greene avenue relief sewer, and in the proposed Classon avenue relief sewer built also to divert storm water from the Greene avenue relief sewer, but at a point about one and a quarter miles above where the Gold street relief sewer connects.

Another relief sewer of a different nature, and serving a different purpose is the Gowanus canal flushing tunnel, extending from the head of Gowanus canal under Degraw street to the harbor, with a nine-foot propeller pump to force the water of the polluted canal through the tunnel to the swift waters of Buttermilk channel. The water pumped out of the canal will be replaced with harbor water flowing up the canal towards the pump, thus tending to improve the condition of the canal and abate the nuisance now prevailing there. This beneficial result will be assisted by the operation of the Gold street relief sewer which will divert all the dry weather sewage from the 15-foot Greene avenue relief sewer which heretofore has discharged into the head of the canal.

In The Bronx it has been found necessary to relieve the old Brook avenue, or Webster avenue sewer of its flood waters at a point about midway of its length by means of a large tunnel running westward from Webster avenue at Wendover, and emptying into the Harlem river just above Highbridge. This, however, is only a temporary relief, as when the watershed tributary to the old sewer becomes fully built up the run-off will increase so greatly that another sewer, at least as large as the present one, will have to parallel it to carry off the storm water refused by the present sewer.

Other difficulties in The Bronx have been experienced in the Bungay creek and Leggetts creek watersheds, outletting at East One Hundred and Forty-ninth street and Tiffany street respectively. To meet this condition there has recently been built the Truxton street sewer, 7 feet 3 inches by 11 feet 6 inches in size at the outlet. This sewer taps the territory most affected and gives additional sewer capacity for the conveyance of storm water to the East River.

Queens Borough is so sparsely built up, with the exception of the Long Island City district, that the impending drainage difficulties have not been foreshadowed by past experiences. This, however, will be the most difficult and most expensive borough to sewer in Greater New York, owing to the great lengths of relatively level territory, and the availability and desirability of the borough for residential, business and manufacturing purposes, enhanced by its prospective connection with Manhattan through the Pennsylvania Railroad tunnel and by the proposed creation of a great harbor in Jamaica bay. With great centers of population on both Jamaica bay and the East river relief and intercepting sewers, with extensive pumping stations and purification works will be a necessity.

One of the large sewers in Queens is the 15-foot Brooklyn-Queens interborough sewer now under construction. This will discharge storm water into the head of Newtown creek and sewage or dry weather flow into the Johnson avenue sewer in Brooklyn, which outlets into the East river at South Fifth street.

Another large intercepting sewer has been proposed extending north from Elmhurst to Hell Gate and emptying at the foot of Winthrop street. This, with the Theodore street outlet sewer would serve to collect the dry weather flow of the entire territory between Long Island City and the Flushing district. It is considered too expensive for immediate necessities, however, by the Bureau of Sewers, and its execution will be delayed as long as possible.

In the New Jersey district the tendency is for several municipalities to join forces to secure sewerage facilities. Among the existing joint sewers are:

(a) The Union outlet sewer of Montclair, Orange, Bloomfield and Glen Ridge.

(b) The Joint outlet for South and West Orange, Vailsburg, Newark, Summit, Elizabeth and other towns to the west of Newark.

(c) The Cranford-Rahway outlet, taking the sewage of Cranford and part of that from Rahway to an outlet into the Rahway river, a mile or so below Rahway.

(d) The Millbrook sewer of Newark, through which the East Orange sewage is discharged into the Passaic.

(e) The Jersey City-Bergen joint sewer for the relief of sections of both of those communities, and discharging into Penhorn creek, a tributary of the Hackensack river.

There are also proposed two other joint sewers for this general district:

(a) The Passaic valley sewer planned to take the dry weather sewage flow of Paterson, Passaic and Newark, with all the smaller intervening towns out of the Passaic and discharge it into New York harbor near Robbins Reef, and

(b) A sewer for the Hackensack valley to take the Englewood, Ridgefield and Ridgefield Park sewage, as well as that of other settlements in that valley, to a purification plant on Peapack creek near its confluence with the Hackensack river.

Sewers to intercept the dry weather flow of the sewage for delivering to more suitable outlets, have been built in Newark, Elizabeth and Jersey City, which latter city has built several storm relief sewers to protect property in different sections from sewer floodings.

In the Bronx valley district the towns away from tidewater have joined in the construction of the Bronx valley sewer which is to take the sewage of White Plains and all the towns to the south as far as Mt. Vernon, to an outlet into the Hudson river just above The Bronx borough line. The work on this sewer is under way.

Pumping Plants. Pumping, to get rid of the sewage, is resorted to at the following places:

(a) *Newark, N. J.* The dry weather flow of sewage of about one-third of the city is lifted from the interceptor and discharged into Newark bay. A small pumping station is also in operation in the Meadow brook system.

(b) *Elizabeth, N. J.* The dry weather flow of sewage is lifted from the interceptor and discharged into the Joint outlet sewer.

(c) *White Plains, N. Y.* Part of the town's sewage is lifted at an ejector station whence it flows to the disposal works.

(d) *Brooklyn, N. Y.* 1, East New York purification plant; 2, Sheepshead Bay purification plant; 3, Coney Island purification plant, caisson No. 2; 4, Coney Island purification plant, caisson No. 3 (at each of these four plants the sewage is lifted from the collecting sewers to the sedimentation basins); 5, Gowanus canal flushing tunnel (in construction, see description).

(e) *Queens Borough.* 1, Jamaica purification plant; 2, Elmhurst purification plant; 3, Far Rockaway purification plant. At each of these plants the sewage has to be lifted from the collecting sewer for discharge into the sedimentation tanks. At Far Rockaway ejector stations are also used to lift the sewage from low to higher level sewers.

SECTION II

METHODS EMPLOYED IN DESIGNING SEWERS

Determination of Quantity of Sewage and Storm Water. In all the Boroughs of The City of New York and in the other towns in both the Westchester and the New Jersey districts the older sewers were not designed under a system taking into account the quantities of sewage flow to be expected, the velocities, the proper capacities, or the proper forms of outlets. Of the oldest, many were built by private citizens to drain their properties, or by the towns to get rid of surface water, houses being later connected thereto.

In more recent times various attempts were made to place the designs on a rational basis. The general data upon which the calculations have been based in preparing the designs for the sewers in several of the different communities within the metropolitan sewerage district will be described below.

Quantity of Water Reaching Sewers. The quantity of water expected to reach the sewers in a given unit of time, or the rate of run off from a given area, is determined in the different municipalities by the use of various formulae. In Manhattan, Newark and Hackensack these quantities are estimated by the formula deduced by Rudolph Hering, C. E., from the gaugings of certain sewer flows from representative areas in The City of New York. This formula is as follows:

$$Q = cr A^{.85} \times S^{.27}$$

For the New York conditions the values of cr are 1.02 for suburban areas, 1.39 for built-up areas and 1.64 for completely built-up areas. A , in the formula, is the area drained, expressed in acres. S is the average slope of the area in feet per thousand measured along the flow line.

For Newark the figures used are:

$c = 1.0$ for suburban area.

1.25 for well built-up area.

1.50 for completely built-up area. taking r at 1.5 inches per hour.

In Brooklyn McMath's formula is used taking a maximum rate of rainfall of three inches per hour for a storm of 30 minutes duration. In The Bronx and Richmond the quantities are determined from the formula $Q = C I T$ in which Q equals cubic feet per second of run-off, C the percentage of impervious surface, I the intensity of the rainfall in inches per hour and T the elapsed time in minutes. For the Bronx I is found from the formula $I = \frac{120}{T + 30}$ For Richmond I is taken as equal to $\frac{105}{T + 25}$ following a five-minute rainfall at the rate of 3.5 inches per hour.

In the Borough of Queens the run-off is determined from rational additive methods using I , the intensity of the rainfall, as equal to $\frac{72.5 T - 299.85}{T (T + 4.14)}$ following a ten-minute rainfall at the rate of three inches per hour.

In Manhattan the allowance for impervious surfaces is of 50 per cent. to 80 per cent.; in Brooklyn, 50 per cent. to 75 per cent.; in The Bronx, 14 per cent. to 75 per cent.; in Queens, 31 per cent. to 81 per cent., and in Richmond, 36 per cent. to 82 per cent. The allowances for impervious surfaces in The Bronx are based on an analysis of the rate of flow in several cities (See Vol. LVIII., page 450, Trans. Am. Soc. C. E.). In Queens, the percentage of impervious surface is based on Prof. Ogden's analyses of Kuichling's general investigations. In the various municipalities an allowance for the percolation of ground water into the sewers is made as follows: Manhattan, 0;

Brooklyn, 0 to .003 cubic foot per second per acre; The Bronx, no allowance made for combined sewers, but half the capacity is added for ground water to the sanitary sewers; in Queens, an allowance of 20,000 to 75,000 gallons per mile of sewers per day is made; in Richmond, no allowance is made for combined sewers, but an allowance of from 10 to 50 per cent. of the maximum flow is made for sanitary sewers. For the Joint outlet sewer an allowance of 25,000 gallons per mile per day was made, but the actual leakage was found not to exceed about 15,000 gallons.

The assumed population per acre on the watershed in Manhattan is determined from the census returns; in Brooklyn it is assumed to be 100 per acre and upwards; in The Bronx, 100 per acre and upwards; in Queens, 50 to 125 per acre; in Richmond, 40 to 160 per acre; in Newark, 90 per acre; in Elizabeth, 87 per acre; in Hackensack, 40 to 75 per acre. The Joint outlet was designed for an ultimate population of 106,000 persons.

The assumed dry weather flow in the sewers in Manhattan is taken as equal to the water consumption; in Brooklyn it is assumed to be 100 gallons per capita with variation according to the water consumption; in The Bronx, 125 gallons per capita with three-quarters of the quantity running off in the sewer in 12 hours. In Queens it is assumed to be from 75 to 125 gallons per capita; in Richmond, 125 gallons per capita with 70 per cent. running off in ten hours; in Newark, 75 gallons per capita with 60 per cent. running off in eight hours; for the Joint outlet sewer, 140 gallons per capita of ultimate population; in Elizabeth, 50 gallons per capita, half running off in the sewers in six hours; in Hackensack, 60 gallons per capita with half running off in eight hours. The velocity of flow and capacities of the sewers are determined in Manhattan, Brooklyn, The Bronx, Queens, Richmond, Newark, the Joint outlet sewer, Elizabeth, Jersey City and Hackensack by the use of Kutter's formula. In Kutter's formula the value of n , which takes into account the roughness of the interior surface of the sewer is assumed for pipe sewers to be, in all the cities, 0.013; for brick sewers in Manhattan, Richmond and Jersey City it is taken as 0.013 and in Brooklyn and The Bronx and Queens, Richmond, Newark and Hackensack at 0.015. For concrete in Manhattan is used 0.011; in Brooklyn, Queens, Newark, 0.015; in The Bronx, 0.014, and in Richmond, 0.011 for smooth finished concrete.

Sizes. In Manhattan the largest sewers are as follows: Two entering at Manhattan street, 7 feet and 7 feet 8 inches in diameter, which drain 633 acres; three sewers at West Forty-second street, equivalent to an 11-foot 6-inch circular sewer; three sewers at Clarkson street with a combined area equal to a 10-foot 8-inch circle; three at Canal equivalent to one 13-foot circular sewer; one at East Forty-ninth street equivalent to an 8-foot 9-inch circular sewer; one at East One Hundred and Tenth street

draining 700 acres and with a section equivalent to a 10-foot circle, and one at East One Hundred and Fifty-first street draining 330 acres to the Harlem river and being 9 feet 6 inches in diameter. The greater number of Manhattan's sewers are elliptical or egg-shaped, though many are circular and some rectangular with reinforced concrete tops and sides.

In Brooklyn the largest sewers are the Brooklyn-Queens interborough sewer with an outlet section equivalent to a circle of 16 feet diameter; the South Fifth street sewer, with a diameter of 12 feet; the Gold street relief sewer, 14 feet diameter; the Kent avenue sewer, 9 feet diameter; the Gowanus canal flushing tunnel, 12 feet in diameter; the Greene avenue relief sewer, 15 feet diameter; the Forty-ninth street sewer, 10 feet diameter; the Sixty-fourth street sewer, 15 feet diameter; the Ninety-second street sewer, 11 feet diameter, the Van Sicklen avenue sewer, leading to the East New York purification works, 15 feet diameter and the 10-foot sewer leading to Paerdegat basin.

In The Bronx the largest sewers are: The Brook avenue sewer, 11 feet 2 inches in diameter; the Tiffany street sewer, 10 feet diameter; the Jerome avenue sewer, 9 feet 6 inches diameter; the Broadway outlet, 16 feet 6 inches diameter; the Farragut street sewer, 15 feet 6 inches diameter; the Webster avenue relief tunnel, 13 feet 6 inches diameter; the Truxton street relief, 11 feet 6 inches by 7 feet 3 inches, and Lafayette avenue, two 10-foot by 8-foot sewers, and one 12-foot by 9-foot sewer.

In Queens the largest sewers are the Harris avenue sewer, 7 feet 8 inches by 7 feet 7 inches; the Webster avenue sewer, equivalent to a 14-foot diameter circular sewer; the Hoyt street sewer, 8 feet by 12 feet; the Ingleside-Flushing outlet sewer, 9 feet diameter, and the Fifth avenue outlet at College Point, 5 feet diameter. The largest sewer in Queens is the Brooklyn-Queens interborough sewer with a section equivalent to a 16-foot circle; this, however, has been enumerated among the Brooklyn sewers as its storm water outfall is in Brooklyn into Newtown creek, and sanitary outfall through Johnson street sewer into East river.

Richmond has very few large sewers, the lines being as a rule short and steep. The only ones of special note are the Nautilus street sewer, draining 367 acres, and 6 feet 6 inches in diameter, and the Canal street storm water sewer, under construction, and 9 feet 3 inches in diameter.

If all the sewers in each borough of New York were combined into one large sewer their areas and diameters would be as given in the following tabulation:

SUMMARY OF INVESTIGATIONS

TABLE I

COMBINED AREAS OF SEWERS IN THE CITY OF NEW YORK

Borough	Total area of sewer outlets in square feet	Diameter of circle having same area as the combined areas of all sewers in the Borough	Number of persons for whom one square foot of sewer area provides sewerage	Square feet of sewer opening provided for each one thousand persons (1905)	Square feet of sewer area provided for each square mile of borough
Manhattan.....	2,500	56' 5"	840	1.19	114
Brooklyn.....	2,097	51' 8"	645	1.55	36
The Bronx.....	763	31' 2"	356	2.81	13
Queens.....	628	28' 3"	315	5.38	5
Richmond.....	317	20' 1"	230	4.32	5
Total.....	6,305	89' 8"	645	1.57	20

That the discharge of sewage into the harbor waters would constitute a stream of significant size, if concentrated into one is indicated by the figures given in the above table. The total volume of discharge, during a storm of sufficient intensity to cause the sewers to run full, would be equivalent to a stream as wide as the East river at the Brooklyn Bridge, running four feet deep, with a mean velocity of four feet per second.

The relatively greater sewerage development in Manhattan, than in Brooklyn, The Bronx, Queens, and Richmond, is shown in the last column.

Other notable sewers within the metropolitan sewerage district are the Bronx valley sewer, 6 feet in diameter, opposite Mt. Vernon, and 8 feet at the Hudson river portal and draining sewage only from the towns in the valley between White Plains and its outlet; the Millbrook sewer in Newark, which has twin outlets of horse-shoe shape, each 6 feet 9 inches by 9 feet 3 inches; the Polk street sewer, also in Newark, an elliptical section with long axis horizontal, 8 feet by 7 feet; the 7-foot 10-inch circular sewer in Paterson draining an area of 1,504 acres to the Passaic at Market street; the Joint outlet sewer for South Orange and other municipalities, 6 feet diameter at its outlet into Kill van Kull, at Elizabeth; the creek sewer, 4 feet by 9 feet, in Hackensack; the 8-foot sewer in Twelfth street, the two 8-foot 9-inch sewers in Carteret street, and the 7-foot sewer in Van Winkle avenue in Jersey City; and the three sewers with rectangular section 8 feet by 8 feet discharging into the slip at the foot of Provost street, Park avenue and Bloomfield street, respectively, in Hoboken.

Shapes and Materials. No standard shapes appear to be adhered to in any of the municipalities.

In Manhattan, egg-shaped sewers predominate except for the larger sizes, which may be circular, horse-shoe or rectangular in section. Most of the sewers are of brick, but there are a few pipe as well as concrete sewers.

In Brooklyn every conceivable form and material for sewers has been employed. The oldest sewers are little else than rough, rectangular, stone drains with poorly paved bottoms. Brick is largely used in circular sewer sections, but vitrified pipe, cement pipe, plain and reinforced concrete are all well represented, concrete particularly in some of the recent constructions.

Jersey City has several large riveted steel sewers running under pressure to convey the sewage from the high ground over the cliffs to tide water. A few cast-iron sewers are also used in that city under similar conditions as well as for outfalls.

Twin sections of horse-shoe or rectangular shape are used in many places, notably Manhattan, The Bronx, Brooklyn and Newark, the largest of all being the triple section in The Bronx, now under construction and consisting of a central opening 9 feet by 12 feet and two side openings 8 feet by 10 feet each, discharging into the East river at the foot of Lafayette avenue.

While not the largest, the East One Hundred and Tenth street and East Forty-ninth street sewers in Manhattan probably discharge a greater quantity of domestic sewage daily than any other two in the metropolitan district; the South Fifth street and the Forty-ninth street sewers in Brooklyn would probably come next in order.

But all these large sewers sink into insignificance in comparison with the proposed Passaic valley sewer, planned ultimately to discharge into the center of New York bay at least 40 times the amount of house sewage discharged daily by any single sewer now entering the harbor.

Ventilation. In practically all the old sewers along the waterfront, and in many of the newer ones, ventilation is deficient and consists merely of the drawing of air into the sewer through perforations in the manhole covers and its expulsion again through the same perforations laden with diluted sewer air in accordance with changes in temperature and volumes of sewage flow. No provisions are made in the older sewers for continuous circulation of air into the perforated manhole covers and out at the tops of the houses through the soil pipes, as disconnecting traps are almost universal in this district. With the ends of the sewers tide-locked, or closed with flap gates to prevent the wind from blowing into the open ends the air in the sewers is usually foul, particularly in the lower stretches. When coated with decomposing sewage and grease occasional gusts of air forced out by changed conditions of pressure within the sewer are generally laden with these odors. The condition is

much aggravated where steam is allowed to enter, or where illuminating gas, or gasoline or other volatile fluids escape into the sewers.

The odors are usually worse from the manholes near the waterfront where the tide backs up into the sewers. The rising and falling of the water surface twice daily displaces and draws in again with each tide a volume of air equivalent to the tidal prism within the sewer. The greater quantity of this air escapes through the perforations of the manhole covers in the portion of the sewer affected by tidal influence.

Flushing Arrangements. In Manhattan sewers are cleaned by hand when the accumulations make this necessary, or on complaint of flooding. There are no flushing gates in the system and no flush tanks. The only flushing the sewers receive is with a hose, which is rarely used. The same general statement is true with regard to all the combined sewers within the territory except those in Hoboken. The Hoboken sewers, with few exceptions, lie so low and have such flat grades that to prevent too great an accumulation of sediment in their inverts sluice gates on the outlets are lowered and raised at the change of tides by service gate keepers, thus, in a measure securing a flushing action.

The separate sewers in several of the districts, notably in Westchester County and New Jersey have flush tanks on the ends of lateral sewers. They are not as extensively used, however, as desirable.

Outlets. In Manhattan intercepting sewers have not been favored as against independent outfalls for each sewer. It is believed by the Bureau of Sewers that multiplicity of small outlets assures better dispersion of the sewage and less likelihood of offensive conditions and better grades for the outlet sewers, particularly along the streets bordering the harbor. Many of the Manhattan sewer outlets are placed so low that tides back up in them for great distances. The older sewers which originally discharged at the bulkhead line have mostly been extended to the pierhead line.

In Brooklyn and Queens many expanses of flat land with reverse slopes make problems of sewerage very difficult. In the older section of Brooklyn and in Long Island City sewers discharge at the bulkhead at the foot of practically every street running to the waterfront. The outlet sewers built of late years have tended more to concentration as exemplified by the South Fifth street, Sixty-fourth and Ninety-second street sewers in Brooklyn. Queens has no established policy with respect to outlets but will soon be compelled to consider the question.

In The Bronx the grades in the lower portions of some of the sewers are so low that high water backs up great distances causing deposits and also flooding streets during rainstorms from the gorging of the sewers. Many of the sewer outlets have been

designed with capacities far in excess of present requirements to guard against similar experiences.

In Richmond the policy is to discharge the storm water at the bulkhead line and carry the house drainage flow in a small pipe out to the pier head line.

SECTION III

METHODS OF MAINTAINING SEWERS

In Manhattan the sewers are inspected and cleaned only on complaint. The force is insufficient to properly maintain the system, although the 1909 results were far superior to those of previous years both as to the quality of work done and the quantity and cost. The sewers are not flushed but are cleaned by hand after sludge accumulates from 10 inches to 20 inches in depth. Street sweepings are regularly pushed into the basins or flushed into the sewers, against orders, by the employees of the Street Cleaning Department.

Inspections in Brooklyn are also only made on complaint. The regular cleaning force is said to be sufficient to take care of basins and small sewers but not of the large ones. A machine has been perfected for cleaning the large sewers. Street sweepings to some extent go into the basins and largely increase the cost of cleaning. The asphalt streets are kept fairly clean; but there are many rough pavements and macadam roads in the borough from which dirt washes into the sewers.

No regular sewer inspections are made in Queens. Distances are great and costs consequently high. The force seems insufficient.

In The Bronx inspections are made by the foremen of the cleaning gangs. The cleaning force is sufficient except during large falls of snow. The Brook avenue sewer needs cleaning very urgently; efforts to clean it with the regular force make no apparent reduction in the amount of deposit therein.

Sewers and basins are regularly and effectively inspected and cleaned in Richmond. Stoppages rarely occur. The water in the catch basins is pumped out by the use of portable centrifugal pumps to facilitate cleaning. The cleanings from basins near the garbage incinerator are burned.

Inspections in Jersey City are not regular, although the cleaning force is said to be sufficient. Street sweepings are not supposed to be pushed into basins. Cleaning many of the sewers can only be done at low tide.

In Hoboken inspections are not regularly made; the sewers are cleaned only when they fail to work.

Inspections are not regularly made in Bayonne; all basins are cleaned in the spring and at other times on complaint. The force is not sufficient.

No inspections are made in Elizabeth, the sewers being cleaned at varying intervals of time. The streets are kept fairly clean and the sweepings are kept out of basins.

In Newark the cleaning gangs, which are said to be sufficient, have sections assigned which they cover with regularity. Sweepings are not allowed to be pushed into basins. Streets are kept very clean.

In Paterson the cleaning of sewers is not carefully done, many of the sewers being partially filled with deposits. Many manhole heads have been covered by paving.

The Joint outlet sewer is under the supervision of two regular inspectors who patrol a given section and report weekly to the Chief Engineer.

SECTION IV

METHODS OF DISPOSING OF THE SEWAGE

Purification Plants. The cities having purification plants are as follows:

Brooklyn:

East New York plant.....	treating daily	12,000,000	gallons of sewage
Sheepshead Bay No. 4.....	treating daily	1,750,000	gallons of sewage
Coney Island No. 2.....	treating daily	1,800,000	gallons of sewage
Coney Island No. 3.....	treating daily	700,000	gallons of sewage

Queens:

Jamaica plant	treating daily	1,500,000	gallons of sewage
Far Rockaway plant.....	treating daily	600,000	gallons of sewage
Elmhurst plant	treating daily	500,000	gallons of sewage
White Plains plant.....	treating daily	1,000,000	gallons of sewage
Tuckahoe plant	treating daily	200,000	gallons of sewage
Bronxville plant	treating daily	100,000	gallons of sewage
Mt. Vernon plant.....	treating daily	2,000,000	gallons of sewage
New Rochelle plant.....	treating daily	700,000	gallons of sewage

The total quantity of sewage treated at these 12 plants in the seven different cities amounts to between 22,000,000 and 23,000,000 gallons daily.

None of these plants except that at Mt. Vernon is modern in plan or design or has for years been other than a makeshift. Complaints have been lodged with the State Board of Health against most of them and numerous investigations and reports have directed public attention to their inefficiency as well as in some cases to the earlier manner of the operation.

The effluents of all the chemical precipitation plants in the above list are little better than can be had by simple subsidence for a proper length of time, and such an effluent will be in a putrescible state a few hours after leaving the plant. As a result, the waters into which the effluents of these plants are discharged are uniformly in a foul condition during the summer weather and frequently so at other seasons of the year.

One other attempt at partial purification is made in Brooklyn, in connection with the sewage discharged into Paerdegat channel. A screening arrangement and grit chamber remove from the sewage a very small percentage of the suspended matter. This is regarded by the Bureau of Sewers of Brooklyn as a temporary makeshift only, and in fact it is due to the department to record in this connection that the four other plants are inheritances and their unsuitability, unfitness and inefficiency fully realized and regretted. Plans have been made for new plants of modern design to replace the four now in service. It is the intention to build a new plant at East New York, another at Paerdegat basin, a third at Sheepshead Bay and a fourth at Coney Island. The locations for each new plant except that at Paerdegat basin will be at the site of the present works. The location for the Paerdegat plant has not yet been definitely selected.

The Coney Island plant is the only one for which the money has been appropriated; plans are now ready for the work. The general scheme for this section of Brooklyn is to intercept the dry weather flow in all the sewers draining to Coney Island creek, Sheepshead bay and Jamaica bay and purify the sewage by screening, settlement in hydrolitic tanks, sprinkling filters and secondary subsidence, at the nearest one of the four plants proposed, before discharging into the water. Sludge is to be pumped to sludge tanks or towed out to sea.

No plans have so far been announced for improving the conditions with respect to sewage purification at the Jamaica plant in Queens County, nor the Elmhurst plant where it is said a significant portion of the sewage leaks out through the bottom instead of passing through the plant properly.

The plants at Bronxville, Tuckahoe and White Plains, it is assumed, will be done away with when the Bronx valley sewer, now under construction, is completed.

The Mt. Vernon plant is practically completed but not yet in operation; it should be a great improvement over any of the existing plants, but time only can tell whether or not its operation will be conducted with that care and intelligence necessary to insure a continuance of good results.

Disposal into Adjacent Waters. In ten of the cities in the metropolitan sewerage district with a population of 4,484,000, sewage amounting to 460,000,000 gallons daily is discharged into the neighboring tidal waters without purification of any sort.

In 25 of the cities, with a population of 479,000, sewage amounting to at least 30,000,000 gallons daily is discharged into neighboring fresh water streams of relatively small size and without purification.

All the larger cities, except Paterson, are on tidal waters and discharge the greater part of their sewage therein through combined sewers without treatment.

The effluents from all the so-called purification plants discharge into nearby water courses or tidal estuaries.

The most important fact shown by a study of the outlet conditions of the sewers around the harbor waters is the almost universal prevalence of nuisances in their immediate vicinity, and the extensive evidences of pollution, offensive to the eye, even though not to the olfactory sense, in practically every portion of the harbor from Throgs Neck to the Narrows, and from the mouth of the Rahway river to Spuyten Duyvil creek.

In Manhattan the Bureau of Sewers does not admit that the discharge of sewage at the pierheads causes any nuisance. It is held by the Bureau that the dumping of garbage from boats, and litter from piers, greatly exceeds in its offense to vision the pollution due to sewage. While there may not be direct and visible injury to the public health from breathing air laden with the effluvia of fresh or decomposing sewage the practice which leads to this result is insanitary and should be abolished. The placing of floating bathing establishments near sewers, as well as the washing of the shores of bathing beaches with sewage, is a decided nuisance and menace to the health of the patrons thereof. The present popular conception of a nuisance is undoubtedly more strict than it has been in the past, and it seems reasonable to suppose that future sanitary requirements will establish higher standards than now prevail. The bathing of the shores of Manhattan Island with the raw sewage of its estimated 3,800,000 inhabitants in 1940 would no doubt be considered a very great nuisance at that time.

Gowanus canal and Newtown creek are the worst points of pollution in Brooklyn. The discharge of raw sewage into Jamaica bay is prohibited by the State Board of Health but this is distinctly violated by the discharge into Paerdegat basin of the raw sewage from three large sewers. The disposal plants at East New York, and Jamaica offer no protection to the shellfish industry of Jamaica bay but on the contrary often give a false sense of security.

Jamaica bay receives the effluent from the Jamaica and Far Rockaway plants in addition to the sewage discharged by private sewers from the remaining portions of the Rockaways.

A large sewer at Fifth avenue and Tenth street in College Point discharges at the bulkhead and causes a nuisance in that portion of Flushing bay. The pollution of Newtown creek is said to be mainly due to manufacturing wastes.

The Harlem river is polluted from end to end by the sewers of The Bronx, but little complaint is heard owing to the nature of the surroundings.

No complaints of nuisances are made in Richmond, although the shores are in places in a filthy condition.

Penhorn creek is badly polluted by the sewage of Jersey City, and has been complained of to the State Board of Health. The Newark bay outlets are complained of by Bayonne. Mill creek in the heart of Jersey City is made up entirely of sewage. The sewer outlets into the Hudson river are at the bulkhead line and pollute the water of the slips so that the ferry boats and steamers are docked in it.

The Hudson river outlet conditions in Hoboken are the same as at Jersey City. Emphatic complaints have been made by the steamship companies.

Complaints by Bayonne against sewer outlets into Newark bay have resulted, in three instances, in carrying the dry weather flow in small cast iron pipes out to deep water. Bayonne is opposed to any further pollution of Newark bay.

Complaints and agitation in Elizabeth have resulted in the construction of an interceptor skirting the Elizabeth river to carry away all of the house drainage now emptying into it. The odors from the river in warm weather were unbearable. No complaints are made of sewage emptying into Kill van Kull, although it is recognized that the time will come when this pollution will have to cease.

The relief from pollution of the Passaic by Newark, Passaic, Paterson and other cities on its banks is now and has been the object for which the Passaic Valley Sewerage Commission has been working almost continuously for eight years.

The Rahway river is badly polluted and many complaints are made by residents along its banks particularly in Cranford. Shellfish are killed in the lower stretches of the river by the pollution.

SECTION V

FAULTS OF THE SEWERAGE SYSTEMS

Tide-Locked Sewers. It seems to have been the policy of the bureaus of sewers of all the municipalities bordering on New York harbor to place the outlets of the sewers so low as to be submerged at high tide, and in some cases at mean tide. Attention

has been called to Col. Julius W. Adams' comment on this practice and its evil consequences as long ago as 1880. Two ideas seem to have been considered in following this plan, the first being to give the sewer bottom as much slope as possible in the belief that the bottom slope controlled the velocity of flow in the sewers (a principle followed in designing by the Brooklyn Bureau of Sewers until changed in 1907 by the present Chief Engineer, Mr. E. J. Fort) ; and the other that the wind blowing in the open ends of the sewers drove the foul air up into the streets through the perforations in the manhole covers.

The extent to which this practice was carried in early times is well illustrated in the Brook avenue sewer in The Bronx, in which high tide level meets the bottom of the sewer two miles from the outlet.

In some of the Manhattan and Brooklyn sewers the conditions almost find a parallel. In order to show the extent of this evil a diagram was prepared showing two contour lines, one marked 0, which indicates the distances in from the shore that mean high tide reaches in all the principal sewers of Manhattan, The Bronx and Brooklyn, and the other marked +2.0, showing the distance that a tide two feet higher than normal, and such as not infrequently occurs, would reach. It was seen that in approximately 20 per cent. of the area of Manhattan the sewage is backed up by the tides and the deposition of silt and solids favored by the checked velocities.

This feature of the sewers to a large extent is the cause of much of the objectionable odors emanating from the manholes along the water front and in the low districts. The rise and fall of the tide not only drives out all the foul air contained in the sewers, but causes the sides of the sewers to become coated with congealed grease and sewage, in some cases, as revealed by inspections made by the Metropolitan Sewerage Commission, fully a foot in thickness. In the Brook avenue sewer the deposits in the two mile stretch at the lower end are so extensive, and the quantity of detritus washed into the sewer at the street inlets so considerable that the cleaning gang makes no measurable reduction in the depth of the mud, although working practically continuously at cleaning.

Improper Sizes. It is but natural that sewers built years ago to serve the residential or suburban districts of the cities should, as these cities grow and as the impervious areas such as pavements and roofs increase, gradually manifest their inability to take care of the increasing quantities of sewage and storm water, and eventually become nuisances by causing the flooding of cellars and streets even during comparatively small storms. Many such sewers exist to-day, and many districts which have suffered from floods of this kind have been relieved by the reconstruction of the sewers, the construction of additional sewers in the same streets, or the diversion of

the sewage to other so-called relief sewers arranged to take the overflow from the original sewers and discharge it at other outfalls.

Manhattan and Richmond have suffered less from this evil than Brooklyn, The Bronx, Queens, Jersey City and Newark, owing to the relative shortness of the sewers in the first two mentioned municipalities. The floods in Manhattan have usually been located near the water front and have been caused by the choking of the sewers with deposits and by rains occurring at times of high tides.

In Brooklyn the troubles have arisen in many cases by the continuous addition of new territory to districts served by sewers already too small.

The Greene avenue relief sewer is an interesting example of this. Originally built to relieve sewers principally in the Bedford district it was extended to take in a much larger territory. The building up of this area resulted in the gorging of the sewer at every rain; and now two additional relief sewers, one already built and another planned (but not constructed owing to the holding up of the appropriations), each of a capacity in excess of the original sewer are provided for its relief.

Queens has as yet suffered relatively little inconvenience from these causes, being, outside of Long Island City and a few small districts around College Point, Jamaica and Elmhurst, essentially a cesspool district. But the rapid development that will shortly follow as a result of transportation and business interests now contemplated and under way will bring to this borough burdens for sewerage that will be relatively as heavy as for any other section of equal area within the metropolitan district.

In The Bronx heavy expenses have already been incurred for relief sewers to help out the older ones—the Webster avenue relief tunnel and the Truxton street relief sewer being the principal ones. Eventually another sewer of about the same dimensions as the Webster avenue (or Brook avenue) sewer will have to parallel the present sewer, in spite of the construction of the relief tunnel. Similarly, all the other big sewers in that district will ultimately have to be duplicated, when the population increases to the limits already reached in Harlem.

Newark is a well sewered city, with little room for further general improvements. Few troubles are experienced with flooding from sewers, except in the low southern portion. One territory which until recently had given some trouble has been relieved by diverting part of the storm flow from the Rector street sewer to the new central relief sewer.

In Jersey City most of the troubles from small sewers have been on the high lands instead of along the water front, and it is to rectify these that the steel and cast iron sewers, running under pressure were built.

Condition of the Sewers. In all the annual reports of the bureaus of sewers in the different municipalities mention is made of repairs that have been necessary to existing sewers and of reconstruction work that has been done or that will become necessary in order to properly take care of the drainage from different districts. Chief Engineer Loomis estimates that there are approximately 55 miles of old sewers in New York at the present time that will require building, and much work of this nature is necessary in Brooklyn, and soon will be necessary in The Bronx. The principal conditions requiring reconstruction of sewers are their breaking by the settlement of the ground along the water front, the destruction of the mortar joints in the sewers by steam, acids and gases, allowing the crowns to settle, the interference with the grades of sewers by the construction of subways, the readjustment of grades made necessary by the establishment of dock lines and pierhead lines in some cases considerable distances out into the stream from the original shore line, the necessity either for a duplication or a reconstruction of a sewer in order to provide for greater storm flows and relieve flooded districts, and other less prominent causes.

Recent Inspection. In order to ascertain the physical condition of the sewers of Manhattan the Metropolitan Sewerage Commission has, with the co-operation of the Bureau of Sewers and the Borough President, made a careful inspection of many of the sewers.

In a general way these inspections have disclosed some facts of considerable interest. Taken as a whole, the sewers appear to be in a fair condition, there being a few exceptions to this rule. In some sewers have been found distorted shapes, worn out inverts, sunken arches, cracks due to settlement, and in some places irregular holes broken through in the making of connections to the sewer, which holes were never properly repaired.

Certain sewers it was impossible to enter for inspection, owing to the heat from steam and the hot water escaping from neighboring buildings. Other sewers could not be entered on account of the presence of illuminating gas in such quantities as to make inspections dangerous or impossible; in other areas lanterns could not be carried into the sewer to permit inspections on account of the gasoline vapor presumably from automobile garages or other establishments using gasoline and naphtha.

Deposits on Sides and Bottoms of Sewers. Most of the sewers the mouths of which are tide-locked and the bottoms of which lie below high tide were found to contain considerable amounts of deposits of silt and sewage solids forming as a rule a dense deposit difficult to remove without the use of tools. In neighborhoods where considerable amounts of grease escape with the sewage the rise and fall of the tides has coated the sides and tops of the sewers with congealed grease in some cases as much

as a foot in thickness. In the sewers where steam and hot water entered the odors from the cooked sewage are unusually disagreeable.

Such sewers can not be properly taken care of; it reflects no discredit upon the Bureau of Sewers to have found them in such condition with the limited means available to the department for the maintenance or cleaning of the sewers. It is doubtful if with any practicable maintenance force the sewers along the water front of Manhattan could be kept clean.

In Brooklyn and in The Bronx the conditions are not much better excepting that there are fewer sewer outlets in these two boroughs than in Manhattan, and consequently there is a smaller total mileage of sewers subject to tide-locking.

Administrative Difficulties. In Manhattan the sewers are maintained and cleaned under the direction of the Superintendent of the Bureau of Sewers. His men clean the catch basins and the sewers and dispose of the cleanings. A considerable proportion of the dirt which finds its way into the sewers in Manhattan goes in through the catch basins, and it is a matter of common knowledge that the street cleaners under the supervision of the Department of Street Cleaning, in order to lighten somewhat their labors, are accustomed to pushing the street cleanings into the catch basins, thus allowing these to be washed into the sewer for removal by the sewer cleaning gang. This practice is not supposed to be allowed and is punishable by a fine upon conviction, but it is stated by the Department of Sewers that the magistrates practically never convict any of the cases which are brought before them by the Department of Sewers. The same remarks apply to Brooklyn.

In The Bronx a complication arises from the arrangement by which the sewers are built under the supervision of the Bureau of Sewers, but a large number of the catch basins, particularly in the district east of the Bronx, have been built and connected to the sewers by the Bureau of Highways. The basins are turned over to the Bureau of Sewers to maintain when connected. Everything goes into the basins just the same as in the Boroughs of Manhattan and Brooklyn. The ordinances against the dumping of snow, street sweepings and other refuse into the catch basins and sewers is as much of a dead letter in The Bronx as in the other boroughs.

This should be corrected as it permits the workmen of one bureau to saddle upon another bureau the expense of the work they are supposed to do, and further than this to put upon the City an extra expense for the reason that it is much more expensive to take deposits out of sewers by hand than it is to remove them from the surface of the street and place them in the carts of the Street Cleaning Department.

Were the sewers of the cities in the districts so laid that they would have self-cleaning velocities, then catch basins could be dispensed with and all the street detritus

be washed into the sewer in the process of washing the streets. Under existing conditions, however, the dirt that is washed into the catch basins is practically all carried into the sewers, and some of this escapes into the harbor and some of it remains in the sewer. That which washes into the harbor is as a rule removed at small expense by dredging, but that which remains in the sewer is removed only at relatively great expense.

In some districts, as for instance on City Island, the Bureau of Sewers has never built any sewers, those which discharge now at the foot of nearly every street on the island having been built either by the Bureau of Highways or by private persons, and such sewers represent usually a waste of money, as they are seldom of the right size, generally poorly laid out and almost universally inefficient and unsuitable to fit in a properly designed system looking to future requirements.

The Public Service Commission, under the terms of the law giving it existence, has the right to interfere with and reconstruct all sewers met with in the construction of the subways, in New York, but are supposed to file notice with the Bureau of Sewers before undertaking such changes, and the changes are supposed to be made under the supervision of the Bureau of Sewers. As a matter of fact there is a good deal of trouble experienced in Manhattan in this connection. The Public Service Commissions' executives frequently make changes without notification to the Bureau of Sewers, sometimes the changes being of very significant proportions and affecting seriously the sewerage conditions of the districts involved. The principal matters in which the interference affects the sewers is in the changes of grade and elevation necessary to accommodate subway construction. In some cases the slopes of large sewers have been taken completely out for considerable distances, converting these sewers through those stretches into sewers of deposit, owing to the absence of sufficient velocity in these flat stretches to carry the solids in suspension.

Improper Methods of Discharging the Sewage Into the Harbor. When The City of New York was considerably smaller than it is, and when consequently the quantity of sewage discharged from the various sewers was smaller, it was undoubtedly good policy to discharge the sewage at many points in small quantities rather than to concentrate it in large quantities at single points. Conditions now, however, have changed in this respect, the quantity of sewage discharged from each sewer along the entire waterfront of Manhattan being sufficient to surround the city with a field of sewage next the shore. On flood tides this sewage is crowded shoreward under the piers and wharves and in the ferry slips and steamship docks.

SECTION VI

FUTURE PLANS OF LOCAL AUTHORITIES

Disposal. In the construction problems which have already been solved in most of the municipalities bordering New York harbor and the adjacent waters the city authorities have foreseen difficulties of like nature requiring solution in the future. The problems in Manhattan are different from those in the other boroughs, in that they are not due to inherent defects or lack of capacity of the existing sewers, but to interference with these sewers in making arrangements to provide improved rapid transit facilities.

The officials of the present Bureau of Sewers consider that the sewage of Manhattan requires no different treatment for its disposal than its discharge into the surrounding tidal waters at numerous points, as is done at present; no plans, therefore, have been considered by the borough contemplating any change in this method, further than to extend the sewer outfalls from the bulkhead line to the pierhead line as rapidly as funds and circumstances will permit.

In Brooklyn it is fully realized that, on account of the rule of the Department of Health prohibiting the discharge of sewage into Jamaica bay, and for the further consideration that the south shore of Brooklyn is lined with bathing beaches and summer resorts, the area draining toward the south and lying east of Gravesend bay will always have to be treated in some special manner, either by collecting it at certain points and pumping it out to sea, or by concentrating it at certain convenient points for purification, the effluent to be discharged into the nearest available body of water. With this in mind the Superintendent of Sewers and the Chief Engineer of the Bureau visited the principal sewage disposal works abroad and also several of the important works in this country, and after due study recommended the construction of four purification plants for the treatment of the sewage of the portion of the Borough of Brooklyn referred to. Plans have been drawn and the authorization secured for the construction of one of these plants which is to be located near Coney Island. One of the proposed new plants would be located at the site of the present purification plant south of East New York, the second would be located near Paerdegat basin, the exact site not having yet been definitely located; the third plant would be located at the site of the present disposal works at Sheepshead Bay. These plants would be provided with hydrolitic tanks of two, four, six or eight hours' capacity, from which the sewage would pass to a regulating house for delivery under pressure to a system of sprinkling filters. The effluent from the sprinkling filters would flow by gravity into settling tanks of about an hour's capacity, and thence to the canal. The sludge would be pumped to sludge

beds or else direct to scows to be towed to sea. All three plants would be of the same type, and if properly constructed and operated would give an effluent satisfactory in appearance and one which would not putrefy after discharge into the nearby waters. The construction of none of the plants has been authorized, excepting the one at the Coney Island site.

To get rid of the nuisance in Gowanus bay and Gowanus canal caused by the discharge into the head of this canal of the 15-foot Greene avenue relief sewer, as well as numerous smaller sanitary and storm sewers, a flushing tunnel 12 feet in diameter has been constructed from the canal to the harbor, and a large pump is to be installed to pump the canal water through the tunnel to the Buttermilk channel, thereby improving the condition of Gowanus canal.

In Queens it is recognized that difficult problems are ahead owing to the relatively small waterfront as compared with the total area of the borough. A plan has been proposed for taking care of the sewage of the western portion of Jamaica, and the territory lying adjacent thereto and adjoining Brooklyn, by constructing a separate system of sewers leading to the Jamaica purification plant with storm water sewers discharging into one of the estuaries of Jamaica bay. This plan, however, has never taken definite form.

For the Flushing district a plan has been proposed for treating the sewage of the Ingleside district by sedimentation and screening, the effluent to be discharged into Flushing creek.

For the district between Flushing and Long Island City, including Corona, Elmhurst and Woodside, it is proposed to construct a large trunk sewer leading to a point of discharge into Hell Gate and intercepting the proposed Theodore street sewer. This plan if carried out would obviate the necessity for operating a purification plant at Elmhurst; but it is realized that the properties which will have to be assessed for the construction of this very expensive sewer would protest against the assumption of the burden at the present time.

In Richmond the separate system is pretty largely used, and most of the outfalls of the separate sewers are extended out to the pierhead line, while the storm sewers discharge at the bulkhead line. It is felt, owing to the considerable pollution of the Kill van Kull water and to the tendency of this polluted water to sweep toward the Staten Island shore and crowd the local sewage back landward, that some day a more satisfactory and more sanitary method of disposing of the sewage must be devised. While not actually preparing plans for such a contingency the matter is at present discussed in the light of one of two possibilities: either to collect the sewage by means of intercepting sewers and deliver it at convenient points for purification or

put in pumping stations and intercepting sewers and provide for the conveyance of the sewage through a force main to deep water in the ocean to the east of Staten Island.

Notice has been given by the State Board of Health to Jersey City and Bergen to stop the pollution of the Hackensack river and Penhorn creek, and if this notice is properly complied with it will probably involve some form of purification of the sewage as it will be impracticable to collect the sewage of these two cities and pump it back to the Hudson for disposal, the cost of purification undoubtedly being less, all things considered. There are no signs at present that anything is contemplated in the matter of purification in Jersey City.

The Kill van Kull now receives a very large amount of sewage and with the further and probably extensive development and settlement of the Rahway and Elizabeth river valleys the time will come when it will be necessary to treat in whole or in part the sewage discharged therein. This possibility has been appreciated by both Elizabeth and the commissioners of the Joint outlet sewer, and it is understood that when the time comes for the construction of the purification plant Elizabeth and the Joint outlet sewer authorities will combine for the purification of the sewage of all the interested communities at a centrally located purification plant. As a matter of fact the permission granted by the State Board of Health for the construction of the Joint outlet sewer was based on the provision "that should future exigencies make treatment necessary, it would be required."

Newark, Paterson, Passaic and the other municipalities in the Passaic valley below Great Falls at Paterson are looking to the construction of the Passaic valley sewer to solve their sewage disposal question. In order to make the Passaic valley project attractive to Paterson, the cost of construction and operation of the Passaic valley scheme must be less than the cost would be to Paterson of purifying her own sewage independently of the other communities.

Should the Passaic valley sewer not be constructed, or should its construction and the subsequent purification of the sewage involve too great an expense, Newark would still be able to purify her own sewage on land adjacent to Newark bay by making some slight changes in her collection system and locating a purification plant on the meadows not far from the present pumping station of the interceptor.

Cranford and Rahway have both been notified to stop the pollution of the Rahway river by November 1st, 1911, and both towns, therefore, are facing the possibility of the construction of purification works.

While at the present time quite extensive plans are being made for the sewerage of the Borough of The Bronx, particularly with reference to that portion of the borough lying east of the Bronx river, the time is unquestionably coming when the dry

weather flow of sewage from The Bronx will require treatment before discharge into the Harlem, the East river or Long Island Sound. No plans have been outlined for taking care of the sewage of this district other than to discharge it into tide water as at present.

Improvement in Sewerage Systems. The development of rapid transit facilities in Manhattan has necessitated making plans for the construction of several additional subways running through the city from north to south on several avenues. Certain of these lines will be located on streets not far from and parallel to the Hudson and East rivers, and their elevations will be such as to interfere seriously with the present sewers.

The Public Service Commission having the right to alter and rebuild sewers interfered with by the construction of subways will, by the time these various subway lines have been completed, have practically rebuilt the sewerage system of Manhattan as a repair job. That is, as each subway is built it would be necessary to take up, move, lower, or raise practically every sewer interfered with and to extend such reconstruction work as is undertaken in this connection a sufficient distance each way from the subway to provide satisfactory slopes for the sewers interfered with. If only one or two subways were to be built this would not be a serious matter; but should six or eight subway lines traverse the city from north to south the sewerage system would be cut up into a number of short pieces, with numerous inverted siphons. The expense of making these changes which, in the end would leave a patched-up, inefficient system would probably be in excess of entirely reconstructing the system, where interfered with by subway construction.

Having this in mind, the Chief Engineer of the Bureau of Sewers of Manhattan has recommended that the sewerage system in the downtown district of New York be reconstructed as soon as practicable on the separate system, taking the storm water sewers over the tops of the proposed subways.

Mr. Rudolph Hering in a report to the President of the Borough of Manhattan under date of April 21, 1908, after an examination of the plans for the proposed subways recommended the making of the necessary preliminary studies for readjusting the present sewers on the basis of a separate system so as to reach a decision as to future policy and plans, and take advantage of the results before the Lexington avenue subway is built, constructing at once the sewers and drains which may follow along or cross the subway to form a part of a general system suitable for all the new subway conditions in Manhattan.

In The Bronx plans have been prepared for the district east of the Bronx river, to provide sewerage facilities for an area of some 11,000 acres which is at present with-

out such accommodations. The territory east of the Bronx river has very few sewers, the only ones of importance being those which serve the Unionport district and which are not yet completed.

Additional relief sewers are contemplated in the district west of the Bronx river and it is also realized that some of the existing sewers will require paralleling or duplicating as the density of population increases and the sewers are called upon to take care of greater quantities of both storm water and sewage.

In Brooklyn the construction of additional relief sewers is contemplated for the Wallabout channel, the relief of the Greene avenue sewer through the proposed Classon avenue outlet, additional outlets to tide water for improperly sewerred districts in several locations and the possible construction of storm water sewers to relieve the district to the south of Flatbush. Certain areas where reversed slopes prevail will have to be taken care of by the establishment of pumping stations. These are not yet sufficiently developed to warrant the expense of such a provision.

In the Borough of Brooklyn it has been necessary, on account of errors in the assumptions made in the early plans, to practically redesign all the unconstructed sewers called for by the city sewer map; and advantage has been taken of this circumstance to provide in the plans for changes necessary for the readjustment of the new system of sewers to meet the requirements of subway construction.

In Jersey City the Greenville section is badly in need of sewers, but permission to discharge any more sewage into Newark bay has been refused and therefore some method of purification will be required in connection with the sewerage of this district; this circumstance has delayed the formulation of plans and definite action.

In Hoboken careful studies have been made of the possibility of establishing pumping stations at different points to permit of the continuous discharge of that city's sewage into the Hudson river in place of the present intermittent system of discharge; no plan which has seemed feasible and practicable has yet been evolved.

The Joint outlet sewer was designed to have sufficient capacity to take care of the sewage and a limited amount of ground water from the area tributary thereto for many years in the future, but apparently some surface water, or some abnormally large supply of ground water, must get into the sewers as it has been found necessary to connect two 15-inch overflow pipes on the east branch in order to relieve it of congestion during storms. When the sewer was designed it was recommended that a tank with sufficient capacity to store one day's sewage flow be built upon each branch of this interceptor, the object being to provide sufficient storage capacity in the tanks to equalize the night and day flow, thereby practically doubling the capacity of the sewer. It would seem, from the necessity of having to provide the overflows on the east

branch, that it were time to construct the tank although no mention is made that it is the intention so to do.

The most important new sewer work proposed within the metropolitan district is that of the Passaic Valley Sewerage Commissioners for the collection and disposal into New York harbor of the sewage of the towns in the Passaic valley between Newark and the falls at Paterson. Detailed plans for this sewer are now being prepared and authority to construct it has been granted. Its course follows the Passaic river from Paterson to Newark keeping close to the west bank excepting through the village of Passaic where a cut-off is made to save distance. The original plans provide for a sewer extending down the valley to a pumping station on the Newark meadows where the sewage would be screened and settled prior to pumping it through a tunnel underneath Newark bay, the Bayonne peninsula and New York bay, to a point along the western edge of the deep channel of the harbor near Robbins Reef. At this point the tunnel is to be connected with a series of branched pipes having a number of outlets on each for the discharge of the sewage at many points.

Another sewerage project of importance is that for the construction of a sewer in the valley of the Bronx river for the interception and discharge into the Hudson river of the sewage of White Plains and the various communities in the valley of the Bronx between White Plains and Mt. Vernon. From White Plains south the sewer follows the valley of the Bronx river as far as Mt. Vernon where it turns to the southwest until within 300 feet of the north line of The City of New York. At this point the sewer turns and follows parallel to the New York city line in tunnel to the Hudson river where an outlet is to be provided to deep water.

It is stated that both the Passaic Valley and the Bronx Valley Sewerage Commissioners intend to provide a measure of purification for the sewage before its discharge into the harbor. The details of the plans for the treatment have not been made public in either case.

SECTION VII

RATIO OF VOLUMES OF HARBOR WATER AND SEWAGE

Continuous Sewage Discharge. In considering the relationship between the volume of the water in the harbor and the volume of sewage discharged into it, it must be remembered that the discharge of sewage is continuous while the flow of the harbor waters is intermittent.

The exact relationship is not clear, nor can it be made so on account of the complications attending the movement of the harbor waters.

Intermittent Tidal Flows. The harbor waters oscillate backward and forward on the ebb and flood currents, with a trend through the Narrows toward the sea due to the resultant excess of the ebb over the flood.

This resultant ebb flow from the harbor above the Narrows is, in turn, due to the land water plus the resultant flow through the East river, which has been shown to be 1,282.3 million cubic feet per twelve lunar hours or one tidal cycle. The quantity of water in the harbor and the resultant flow through the various divisions of the harbor have been given in the preceding sections.

In Table II is given the result of a calculation which illustrates the ratio of volumes of harbor water and the effluent from sewers.

In any division of the harbor the resultant flow represents the amount of water which passes out during a tidal cycle, and which is replaced from a new source on the next cycle. It, therefore, represents the net change taking place every twelve lunar hours.

TABLE II
RELATION BETWEEN HARBOR WATERS AND SEWAGE
(Quantities are in Millions of Cubic Feet)

	1. Volume of water (1)	2. Resultant Flow One Tidal Cycle	3. Number of Tides to Change	4. Number of Days to Change	5. Sewage per Day Estimated 1908	6. Sewage for Days in Col. 4	7. Percent. Col. 6, Divided by Col. 1
Hudson river.....	13,178.5	1,100.	12.	6.	22.0	132.	1.
East river.....	12,400.	100.	124.	64.	40.0	2,560.	20.
Newark bay (2) and Kill van Kull....	2,547.7	88.	29.	15.	7.1 (4)	106.	4.
Upper bay (3).....	14,240.5	1,282.3	11.	5.5	79.5	437.	3.
Harlem river.....	221.9	22.6	10.	5.	4.8	24.	11.

(1) Volume below mean low water plus half of tidal prism.

(2) 84 per cent. of Newark bay plus Kill van Kull. 16 per cent. passes out through Arthur Kill.

(3) For Upper bay, the resultant flow is taken at the Narrows.

(4) Includes the sewage discharge above the Narrows, with 84 per cent. of Newark bay district.

It is not intended that these percentages shall be taken as accurate, but the underlying principle, namely, the relative pollution by virtue of the continuous discharge of sewage and the intermittent tidal flow, is represented by the figures.

As the water flows, from say the East river, with a full charge of sewage into the Upper bay, the discharge from the river is diluted so that on the change of tide the water returning to the river has a lower percentage of sewage. It is on this account, and on account of the changes that take place in the sewage itself, that the percentages are not accurate.

It is reasonable to suppose that the population of the metropolitan district * in 1940 will be two and one-half times that of 1908. Under these conditions the pollution of the waters of the harbor in 1940 will exceed the proportions which are usually considered safe for the dilution of sewage in a stream continuously running in one direction. This is shown as below :

Future Conditions. The quantity of sewage now entering the Upper bay is about 80 million cubic feet per day, or 40 million cubic feet per tidal cycle. The resultant flow out of the Upper bay is 1,282 million cubic feet, or a relationship of one part sewage to 32 parts water. In 1940 these proportions would change to one part sewage to 13 parts water. The common figure for dilution of sewage entering a stream running continuously in one direction is one part sewage to 15 parts water. Therefore, between now and 1940 it would appear that the limit of the Upper bay would be reached.

The resultant flow through the Narrows is 1,282.3 million cubic feet, which as a continuous flow for 12 lunar hours would be 28,700 cubic feet per second.

In 1908 the population of the metropolitan district above the Narrows was about 6,100,000. Therefore, the cubic feet per second per 1,000 population is about 4.7.

In 1940, the population in the same district above the Narrows will be about 10,800,000. Therefore, the flow per 1,000 population will be about 2.65 cubic feet per second.

When sewage is discharged into water it undergoes certain digestive processes, *i. e.*, the sewage is continually being transformed into simpler compounds, and loses its sewage qualities. These figures, therefore, must be considered as relative only. They show that in 1940 the condition of the water in some of the divisions of the harbor will be polluted beyond the limitations of the sanitary standard generally accepted.

More Information Needed. There are a number of gauges now established and maintained by the United States Government and by the City which record the tidal ranges. These gauges do not establish information from which direct calculations could be made of the quantities of water carried in the main tidal currents, but they do give information upon which the calculations of tidal flow are based.

Advantages of Additional Stations. The main advantage of establishing additional gauges would be to determine whether the tidal movements were being reduced because of encroachment of piers and bulkheads. If, for instance, a gauge was estab-

* A district covering about 350 square miles in each of the States of New York and New Jersey, with Manhattan as center, varying between 15 and 20 miles from the center to the margin.

lished on the Hudson river above Manhattan Island, at some point like Dobbs Ferry or even further north, and the range of tide were there found to diminish from year to year, it would indicate that the tidal movements were being reduced because of such encroachments. For similar reasons, gauges might be maintained in Newark bay, in the Passaic river, and in the Hackensack river.

SECTION VIII

LACK OF CO-OPERATION BETWEEN THE MUNICIPALITIES

The most important imperfections revealed by a review of the methods of sewerage and sewerage administration in force in the metropolitan sewerage district may be divided into three general classes:

- (a) Lack of co-operation between the different municipalities in sewerage matters, particularly with respect to disposal.
- (b) Lack of co-operation between different departments of the same city.
- (c) Lack of uniformity in matters of design and construction.

Sewage Disposal. It is evident that there is no correlation or co-operation between the various municipalities of the district whereby the entire situation with respect to sewage disposal and to the pollution of the surrounding waters can be taken into account in providing for the future sewerage of the different districts. This is wrong in principle and in time will be found to have been wrong in practice.

There are two aspects in which the problem of the sewage disposal for the municipalities within the metropolitan district must be considered, the local and the general.

Up to the present time local difficulties only have been thought worth consideration under the conviction, strengthened by suggestions of the further discharge into the harbor of the sewage of large inland communities (under the plea that the waters of the harbor could safely receive and digest such additional quantities), that much larger quantities of sewage could be discharged into the harbor if properly introduced. This view the Metropolitan Sewerage Commission finds, as a result of long study based on most careful analytical methods and data supported by physical examinations and personal inspections, to be unwarranted. It appears, in fact, that at the present time the general aspect of the case demands attention more urgently than local questions.

In past times when the municipalities now forming the boroughs of New York were small, the population rather widely scattered and, therefore, the quantity of sewage discharged into the harbor waters small in comparison to the quantities now being discharged therein no troubles, no nuisances and no inconveniences were experienced

by discharging the raw unscreened and untreated sewage into the harbor at the bulkhead line. Increased density of population, increased percentages of impervious areas and increased conveniences in the manner of living and the requirements of civilization have gradually changed conditions so that some years ago local nuisances began to manifest themselves in ferry slips, steamship docks, canals and tidal estuaries where the sewage was discharged at the bulkhead line where it was not submitted to proper influences for its satisfactory dispersion. The bureaus of sewers of the boroughs of New York have not considered that the time had been reached when a general account should be taken of the condition of the harbor waters as a whole.

Condition of the Harbor Waters. It may be the impression of many that there is no necessity for considering the protection of the harbor waters as a whole; that the adoption of such methods as will prevent local nuisances and will cause the dispersion of the sewage so as not to be offensive to the eye will be a satisfactory treatment; that the sewage from the Bronx valley, and the Passaic valley and the Hackensack valley, and other districts which will in the future be extensively built up could be indefinitely discharged into the waters of New York harbor without causing trouble. To such it will no doubt be a surprise to learn that at the present time the waters of the Harlem river, and of the East river between Wards Island and the mouth of the Harlem are at practically all stages of the tide surcharged with sewage; and that in practically every part of the East river and Hudson river and the Upper bay as far as the Narrows there are times when the measure of the existing pollution indicates that in these waters the capacity to absorb and digest sewage has been reduced already 50 per cent. and that on the average, the entire harbor shows for the past year a reduction of 30 per cent. of its available digestive capacity.

It is estimated that by 1940 the population that will be resident around the harbor of New York will be about twice the present figures. It is, therefore, clearly to be seen that remedial measures to control the method of discharging sewage into New York harbor should be inaugurated as soon as possible.

In the polluted water the transition point from a water which is inoffensive to one which is decidedly offensive is almost instantaneous and depends upon the amount of dissolved oxygen contained in the water. So long as any dissolved oxygen is present the process of oxidation will go on without offense to the sense of smell although the water may be in a very unsightly condition; but when the dissolved oxygen has all disappeared further oxidation is impossible and the process of decay and putrefaction, with the evolution of offensive odors, begins to take place.

The whole of Manhattan being surrounded with water, and 85 per cent. of its whole area being covered with buildings, paved streets and courtyards, the collection of the

sewage of the entire borough for delivery to a site elsewhere suitable for its complete purification would be too expensive. The same is true for portions of other municipalities within the district.

On the other hand for portions of The Bronx, Brooklyn, Queens and Richmond, as well as all the other municipalities under consideration, sites are available where purification plants could be established for their respective territories, when such may become necessary.

Bearing in mind, further, that by 1940 the quantity of sewage produced by Manhattan will be at least twice the present amount, and that it is now approximately half of the quantity produced in the entire metropolitan sewerage district, it will be seen that the pollution from Manhattan's sewage alone will, by that time, exceed the present pollution from the entire metropolitan sewerage district, which, as has been shown, is now excessive. This consideration alone makes apparent the necessity for the restriction of the pollution of the harbor waters. With no control, the conditions which now prevail in the Harlem and a portion of the East river would eventually extend to the whole East river and to a large portion of the Upper bay and Hudson river.

Plans for Conservation. To avert such a condition it is wiser to face the problem now, while the opportunity exists, and outline a safe and rational policy, economical for all the boroughs, by which the degree of pollution of the harbor waters as a whole may be kept down to proper limits and all the sewerage works of the district be planned to fit into a proper scheme of conservancy without waste of public resources.

If such a plan is not followed, and if license be given to each borough to discharge its raw sewage into the harbor waters without restraint, portions of some of the boroughs which could, for no greater expense, take care of and purify the sewage originating within their boundaries will appropriate the digestive capacity needed by other portions of those, or other boroughs, and multiplications of the nuisances in Newtown creek, Wallabout channel, Gowanus canal and Paerdegat basin will be produced, on a larger scale, in the end of Long Island Sound (technically known as the East river between Throgs Neck and Hell Gate), in the East river, in Newark bay and Kill van Kull, and along the Manhattan and New Jersey shores.

The unrestricted, unrelated discharge of sewage into the harbor waters can not be permitted to continue indefinitely for the reason that the quantity of harbor water available for the dilution of the sewage will, of course, not change materially from year to year, while the quantity of sewage will increase with the population; and the limits to which it will increase are not known. New York is growing, but it is not yet the largest city in the world.

It is imperative, therefore, that a general plan of conservancy be outlined taking into account the difficulties and advantages peculiar to each district, or locality, and determining, in advance of the actual requirements of each section, that policy which will, for the least expense and with the guarantee of proper results, best permit each section to enjoy the advantage of its location without robbing another section of its advantages and rights. The whole question of methods should be worked out with great care, in collaboration with the existing authorities, and in conjunction with the needs and natural advantages of each section, by one authoritative commission which shall represent the entire district without prejudice to the rights of any one section.

It would be desirable if the New Jersey authorities would join with New York in outlining a general plan of conservancy, but such co-operation is not essential. In the boroughs of New York originate the major sources of pollution, and the necessity for action on the part of New York would be imminent even if the New Jersey sewage were purified within the confines of that State. When New York shall have announced plans for improving present conditions, as well as for preventing the creation of further nuisances, there will be no difficulty in securing the effective co-operation of the Federal Government and the State Board of Health to secure such reasonable regulations with respect to the further pollution of New York harbor as will effectively protect all interests.

SECTION IX

LACK OF CO-OPERATION BETWEEN DEPARTMENTS

It is inevitable that in relatively young and rapidly growing communities systems of government should reflect, in a degree, the conditions exemplified in the rapid growths of the communities themselves. This we find to be the case to a considerable extent throughout the metropolitan sewerage district, being manifested, in its light of greatest interest in this discussion, by lack of co-operation between the different executive departments of municipal governments.

Between Sewer, Highway, Dock and Magisterial Departments. One of the principal objects of administrative government is the economical provision and management of works for the public good. It seems academic to point out that to secure reasonable and expected benefits there should be co-operation between the various sub-departments which form co-ordinate parts of the whole.

There are, however, in nearly all the municipalities within the metropolitan sewerage district examples of the reverse of this simple proposition. In Manhattan, for instance, there is an ordinance forbidding the dumping of snow, street sweepings and refuse into catch basins and sewers, and yet street sweepers, when not watched, reg-

ularly push such matter into catch basins. The sewer cleaners can not successfully remove all these matters from the sewers and the Dock Department has to dredge them from the slips; finally the magistrates dismiss the cases when the sewer cleaners have the street sweepers arrested for violation of the ordinance.

Here is one example of the lack of co-operation between the Bureau of Sewers, the Bureau of Highways, the Department of Docks and the City Magistrates. The practical effect is the ignoring of the Sewer Department by the street sweepers under magisterial indifference, the fouling of the catch basins with resulting odors, the filling up of sewers with detritus, and additional work thrown on the Department of Docks. The street sweepers push the sweepings into the sewers as an easier way of getting rid of them than picking them up and throwing them into the Department's carts. It costs very much more to remove deposits from catch basins and sewers than it would to remove the same materials, usually in a reasonably dry condition, from the piles on the street surface; the extra cost is paid by taxpayers.

An instance of lack of co-operation between the street repair and street cleaning departments of New York was shown in the report of the committee on street cleaning in the statement that the extra annual cost of cleaning streets with worn-out and defective pavements would more than keep their surfaces in good condition.

With Respect to Construction and Maintenance. Another direction in which lack of co-operation manifests itself in connection with the sewerage of the municipalities within the district is in the provision, in certain districts, for the building of sewers by or under the direction of the Bureau of Sewers and the catch basins by the Highway Department to be turned over to the Sewer Department for maintenance when built. This frequently results in admitting more storm water into the sewers than they can properly care for, with resultant choking and the backing of sewage up into cellars.

The Public Service Commission and the Bureau of Sewers. The lack of co-operation between the Public Service Commission and the Bureau of Sewers is a matter of serious moment. The Public Service Commission should submit plans in advance, showing what changes are proposed in each locality, and should not make changes until the plans therefor have been formally approved by the Bureau of Sewers; sufficient appropriations should be made to the Bureau of Sewers to permit this service to be rendered promptly.

It is almost certain that with the construction of the many subways planned on the avenues in Manhattan interference with the storm water sewers will be so serious that were a number of these subways to be constructed at one time it would be far cheaper to reconstruct on the separate plan all the sewers interfered with than to

change and reconnect each sewer for each subway interference. In fact, the sewers could not be remodeled to suit the construction of the proposed new subways without the construction of inverted siphons under the subways, which on storm water sewers of such size and character, with no opportunities for overflow, would be clearly inadmissible.

In line with this policy the Metropolitan Sewerage Commission feels that where sewers in the lower part of Manhattan require reconstruction the new sewers should be built on the separate plan, the storm sewers keeping as close to the surface as necessary, and the sanitary sewers low enough to pass underneath the subways in inverted siphons, when these can not be avoided.

Right of Entry for Inspectors. In the matter of the maintenance of the sewers one of the most important defects in the administrative authority lies in the inability of the bureaus of sewers to secure evidence sufficiently strong to warrant convictions of violations of the ordinances against the discharge of steam, hot water, gases, acids and other injurious matters, into the sewers.

The courts require substantial proof that the ordinance is violated by the party against whom the complaint is filed and this is practically impossible to secure. The departmental work would be rendered more effective in this direction by the passage of an ordinance granting the bureaus of sewers, through the inspectors, the right to enter premises and inspect periodically all sewer connections, the same as do the inspectors of the Department of Water Supply, Gas and Electricity. Violations of the ordinance could then be discovered and a stop be put to practices which not only render impossible inspections of the City's sewers in some localities, but also destroy the sewers.

SECTION X

LACK OF UNIFORMITY IN DESIGN AND CONSTRUCTION

Storm Water Allowances. A study of the methods employed in the various municipalities within the district for estimating the quantities of storm water to be provided for in the sewers reveals a great diversity of practice.

Some of these differences can be explained by differences in topographical and surface conditions; the reasons for others are not apparent. This is a fruitful subject for further investigation, and an effort should be made to standardize these methods by long-time gaugings of sewer flows under various conditions in the different districts and the reduction of the results to a rational basis for analysis, comparison and application. The cost of such an investigation if conducted by the

various bureaus under the general supervision of one head would be comparatively slight, and the results of far-reaching benefit.

Designs. In the matter of designs, also, the work should be standardized as much as possible to secure uniform bidding and fair prices.

In the existing works are to be seen examples of every known type and condition. Some of the outfall sewers end at the bulkhead line, some at the pierhead, some out into the open water, discharging on the surface of the water; some are submerged with the ends of the sewers tide-locked practically all the time; some discharge upon salt marshes or into the small canals and channels dug through the marshes for drainage purposes; some have storm water outfalls at the shore line with submerged sewage outfalls leading out to deep water and some discharge under the piers back of the pierhead line. From some of the outfalls dispersion of the sewage seems to be complete and satisfactory; from others it is the reverse. This whole question should be investigated in a practical way in co-operation with the bureaus of sewers and a policy adopted for varying conditions that would insure, where tidal discharge proves proper, the satisfactory disposition of the sewage.

Ventilation. Another matter of importance relates to a uniform and more satisfactory system of ventilation for the sewers, where necessarily placed at so low an elevation as sometimes to be tide-locked. The offensive odors around the manholes in such locations should be done away with by proper ventilation systems. In New York, where troubles of this nature are more prevalent than in the other municipalities in the district, it is the uniform practice to use disconnecting traps on all house connections so that the air from the sewers can not enter the pipes within the buildings. The ventilation of the house pipes is accomplished by the use of an air vent on the house side of the disconnecting trap whereby a current of air is permitted to circulate down into the house sewer and then up to the air above the building through the soil pipe. The adoption of this plan for plumbing confines the ventilation of the public sewers with tide-locked outlets to the ingress and egress of air through the perforations in the manhole covers; it does not insure a circulation of air through the sewers, and hence the air that goes into the sewer comes out again through the same holes into the street, impregnated to a greater or lesser extent with sewer air which, even though not always necessarily objectionable as to odor, usually contains a high proportion of carbon dioxide, a gas which unmixed with air will not support life. As many of the tall office buildings in lower New York have ventilation systems, particularly for the stories below street level, and as the inlets for air are in areaways beneath the sidewalks, the blowers drive through the buildings air of not as good quality as

should be available. This matter should receive attention; the remedy is simple and inexpensive.

Street Washing. Numerous suggestions have appeared in the press within the past year regarding the washing of the streets with water to aid in cleaning in summer and to remove snow in winter. These practices are followed abroad to some extent, and with conspicuous success where the sewers are built upon steep enough grades to permit the solids to be carried through them by the flowing sewage, and when catch basins are omitted from the street inlets; but if followed indiscriminately in New York, and without strict supervision, much complaint and probably suits for damages would result.

At the upper ends of the sewers probably no inconvenience would be felt; but in the flat portions near the waterfront, where the rising tide backs into the sewers, the solids washed in from the streets would deposit in the quiet water and cause obstructions which would be costly of removal or cause the gorging of the sewer and the consequent flooding of cellars and streets. For street washing to be successfully employed there should be no catch basins on the sewers, the sewer grades should be steep enough to insure self-cleansing velocities of flow, and a screen and grit chamber should be arranged at the outlet end of the sewer whence the retained materials could be economically removed. Where applicable this plan is meritorious from a sanitary standpoint, as well as on the score of economical operation.

PART III

Data Collected

CHAPTER I

MOVEMENT FOR A CLEAN HARBOR

In the year 1903 the Governor of The State of New York appointed a board of experts in accordance with a special Act of Legislature entitled "An Act to authorize the appointment by the Governor of a commission to investigate certain threatened pollution of the waters of New York." (Chapter 539, Laws of 1903). The commission so brought into existence consisted of Daniel Lewis, Chairman, Olin H. Landreth, George A. Soper, Myron S. Folk and Louis L. Tribus, Secretary. Dr. Lewis was at the time Commissioner of Health of the State.

THE NEW YORK BAY POLLUTION COMMISSION

The reason for creating the New York Bay Pollution Commission is stated in the first report of the commission, dated March 31, 1905, (Senate Document 39, 1905), as follows:

"The State Department of Health, having for years noted with anxiety the increasing pollution of New York harbor, due to the discharge into its waters, of sewage and factory wastes of all kinds from the different boroughs of the city of New York, the city of Yonkers, and the cities and towns in the State of New Jersey, situated along the banks of the Hudson river, New York bay and their tributaries and estuaries, and this pollution having culminated in the proposed construction of an immense sewer to discharge the wastes from a large territory in New Jersey, not contiguous to the waters of New York bay, brought the matter to the attention of Governor Odell, who thereupon invited legislative action."

The Pollution Commission held its first meeting on June 30, 1903, at which time an outline of procedure was prepared and assignments made to the different members of subjects for special investigation. Each Commissioner reported upon the topic assigned him and these reports were ultimately published as appendices to the Commission's formal reports. In addition to the work done by special assignment, the Commission held frequent meetings, took testimony at public hearings and held joint conferences with the Passaic Valley District Sewerage Commission to learn the details of the Passaic valley project.

First Report. Briefly stated, the commission found the harbor to be seriously polluted; it pointed out that the relation of the waters to climatic and sanitary conditions, as well as to commerce, was "of value beyond computation," and recommended that the waters be protected from pollution by sewage as far as practicable. Two systems of final disposal were considered to be feasible for the district as a whole: First, sewage

purification plants for each local district or municipality; at such works the sewage would be so treated as to make it innocuous and inoffensive when it reached the waters of the harbor. Second, a comprehensive scheme for carrying the crude sewage of the whole metropolitan district lying in New York and New Jersey to sea, either by one or by several great trunk sewers or tunnels. In either case the work suggested would be of such great magnitude that the Pollution Commission felt able to propose it only in barest outline. As far as the Pollution Commission could determine, the idea of disposal at sea offered the more promising solution of the question.

To control the disposal of sewage in future, the Pollution Commission suggested the establishment of a metropolitan district "to include all sections in both New York State and New Jersey which now or in future might sewer into the bay and its tributaries." The Commission advised that,

"Such a district, when authorized by joint State and Federal legislation, should be under the direction and control of a permanent interstate commission, with plenary power to control the discharge of all sewers hereafter constructed, as well as the evolving of a comprehensive plan for ultimately rendering the present chaotic, systemless method of sewage disposal sanitary and suitable for all future requirements."

The Commission declared that necessity already existed for a central authority to not only direct, but to initiate such great public works as were required.

In conclusion, the Pollution Commission protested against the consummation of the Passaic Valley Sewerage Commission's project as then proposed. It recommended that the Legislature authorize the appointment of a Metropolitan District Sewerage Commission to thoroughly investigate the practicability of a comprehensive system for ocean disposal of the sewage of the metropolitan district of New York and New Jersey, advised that the Attorney General of the State of New York be authorized and directed to bring action in the Supreme Court of the United States against the State of New Jersey and the Passaic Valley Sewerage Commission upon his attention being called to any act of the State of New Jersey or the Passaic commission toward carrying into effect the construction of the trunk sewer which had been proposed.

Final Report. The presentation of the report of the New York Bay Pollution Commission was unavoidably delayed until nearly the close of the Legislature of 1905, and action looking to the carrying out of the Pollution Commission's recommendations could not be taken that year. The Legislature continued the life of the Commission for another year, at the end of which time the Pollution Commission made a second and final report. (Assembly Document 76, 1906).

When the first report was submitted technical journals and the daily press of New York gave much publicity to the matters which had been reported upon and commended

fully the work already done and that proposed. Representative bodies gave evidence of being alive to the necessity of action, especially the Chamber of Commerce of the State of New York, the Merchants' Association of New York, the Board of Trade and Transportation, the Maritime Association of the Port of New York, the Produce Exchange, the City Club, the American Scenic and Historic Preservation Society and the Municipal Engineers of The City of New York.

In 1905-6 the Pollution Commission's further studies confirmed the conclusions which had been arrived at in the earlier investigations. The Commission stated that this additional work

“Demonstrated still more clearly the need for full study and the earliest possible consideration of the whole question of preventing the further pollution of the waters in question and the ultimate doing away with even the present causes of contamination.”

THE METROPOLITAN SEWERAGE COMMISSION OF NEW YORK

Appointment. Action in accordance with the recommendations of the New York Bay Pollution Commission was taken in 1906. By an Act (Chapter 639, Laws of 1906) which became law May 25, 1906, the New York Legislature provided for a commission “to investigate and consider means for protecting the waters of New York bay and vicinity against pollution and authorizing The City of New York to pay the expenses thereof.” (Chapter 639, Laws of 1906).

This Act required that the Mayor of the City of New York should appoint five persons, three of whom, at least, should be of recognized skill in sanitary engineering and each a resident of the State of New York, to be a board of commissioners to continue the work of the New York Bay Pollution Commission and extend that work so as to include a number of specific duties.

The following persons were appointed members of this new commission: Daniel Lewis, President, Matthew C. Fleming, Olin H. Landreth, George A. Soper and Andrew J. Provost, Jr., Secretary. It was decided to call the board the Metropolitan Sewerage Commission of New York. On October 5, 1906, Mr. Fleming resigned and Mr. James H. Fuertes was appointed in his place. In January, 1908, the membership of the commission was reconstituted. The reorganized board has remained without change to the present time. The members are: George A. Soper, President, James H. Fuertes, Secretary, H. de B. Parsons, Charles SooySmith, Linsly R. Williams.

The Act in full follows:

CHAPTER 639, NEW YORK STATE LAWS OF 1906

An Act to provide for a commission to investigate and consider means for protecting the waters of New York bay and vicinity against pollution and authorizing the city of New York to pay the expenses thereof.

Became a law, May 25, 1906, with the approval of the Governor. Passed, three-fifths being present.

Accepted by the city.

The People of the State of New York, represented in Senate and Assembly, do enact as follows:

Section 1. The mayor of the city of New York shall appoint five persons, three of whom, at least, shall be of recognized skill in sanitary engineering, to become a board of commissioners for the purposes hereinafter specified. Each of the persons so appointed shall be a resident of New York state. The board shall have power to appoint a president and a secretary from among its members and to engage such engineers, chemists, bacteriologists, inspectors, draftsmen, stenographers, clerks and other employees, and to incur such other expenses in executing the purposes of this act, as may be necessary. The corporation counsel of the city of New York shall be the attorney at law for, and legal adviser of, the board, and shall, upon its request, either personally or through such of his assistants, or other counsel as he may designate, furnish it with advice and aid, in a similar manner as he is required by law to do in the case of the departments, boards and officers of the city of New York.

Sec. 2. It shall be the duty of the board to continue the work of the New York bay pollution commission established by chapter five hundred and thirty-nine of the laws of nineteen hundred and three, and to extend the work of that commission so as to include the following duties:

(1) To make further investigations into the present and probable future sanitary condition of the waters of New York bay and other bodies of water within or adjacent to the several boroughs of New York city and neighboring districts.

(2) To consider and investigate the most effective and feasible means of permanently improving and protecting the purity of the waters of New York bay and neighboring waters, giving attention particularly to the following subjects:

(a) Whether it is desirable and feasible for New York city and the municipalities in its vicinity to agree upon a general plan or policy of sewerage and sewage disposal which will protect the waters of New York bay and vicinity against unnecessary and injurious pollution by sewage and other wastes;

(b) What methods of collecting and disposing of the sewage and other wastes which pollute, or may eventually pollute, the waters contemplated in this act are most worthy of consideration;

(c) Whether it is desirable to establish a sewerage district in order properly to dispose of the wastes, and adequately protect the purity of the waters, con-

templated in this act, and, if so, what should be the limits and boundaries of this sewerage district;

(*d*) What would be the best system of administrative control for the inception, execution and operation of a plan for sewerage, and ultimate sewage disposal, of a metropolitan sewerage district; whether by the action of already existing departments and provisions of government, by the establishment of separate and distinct sewerage districts and permanent commissions in each state, by one interstate metropolitan sewerage district and commission to be established by agreement between the two states, this agreement if necessary to be ratified by congress, or by other means.

(3) To co-operate with any duly authorized body or commission having similar authority in the state of New Jersey, in the joint investigation and consideration of the various subjects specified in this act.

(4) To submit to the mayor of the city of New York in writing on or before February first, nineteen hundred and nine, a full and complete report of its investigations, conclusions and recommendations. Also to submit such definite conclusions and recommendations as may have been reached conjointly by the commission herein established, acting in conjunction with any similar body having similar authority from the state of New Jersey, relating to the most effective and feasible means or plan for permanently improving and protecting the waters of New York bay and the rivers and other bodies of water within or adjacent to the several municipalities in the metropolitan district.

Sec. 3. The members of the commission herein provided for shall, before entering upon the discharge of their duties, take and subscribe the constitutional oath of office.

Sec. 4. Each member of the commission shall have the power to administer oaths and the commission shall have the power to subpoena witnesses and take testimony, and, in addition, shall have all the powers of legislative committees as provided by article three of the legislative law. The members of the commission, and all persons duly authorized by the commission, shall have the right of entry and passage to any place or property on land or water within the state, or under the state's jurisdiction, for the purpose of making surveys, examinations or investigations.

Sec. 5. The commission shall terminate on May first, nineteen hundred and nine, and all maps, results or surveys and examinations, estimates and other papers and matter acquired by the New York commission shall be properly indexed and labeled and turned over to the board of estimate and apportionment of New York city.

Sec. 6. The members of the commission shall receive no salary, but shall be paid their reasonable and necessary expenses actually incurred in the prosecution of their duties, and shall each be paid a just and reasonable per diem compensation, to be determined by the mayor of the city of New York for the time actually and necessarily employed on the work of the commission.

Sec. 7. The comptroller of the city of New York is hereby authorized and directed to raise from time to time, by issuance of corporate stock of the city of New York, fifteen thousand dollars, or such part of this sum as shall be sufficient to pay the expenses of the commission herein provided for. Such corporate stock shall be issued by the comptroller when thereto authorized as provided in section one hundred and sixty-nine of the Greater New York charter. All payments from the sale of such corporate stock shall be made upon proper vouchers, having the authorization of the chairman and secretary or by signatures of a majority of the commission herein provided for, and in accordance with the laws, regulations and practice now in force for the payment of money by the comptroller of the city of New York.

Sec. 8. The secretary of state is hereby directed to communicate to the governor of the state of New Jersey, transmitting a copy of this act and to extend through him an invitation to the state of New Jersey to co-operate with the state and city of New York in carrying out the purposes to be attained by this act.

Sec. 9. This act shall take effect immediately.

Appropriations. This Act of Legislature which provided for the creation of the Metropolitan Commission specified that the life of the board should terminate May 1, 1909. By an amending Act (Chapter 422, Laws of 1908) the life of the Commission was extended to May 1, 1910. At first the Commissioners received no salary; the Act specified that they were to be paid a per diem compensation to be determined by the Mayor of The City of New York. This compensation was eventually fixed at five dollars per day. By the amending act a compensation of \$3,000 per year was allowed each commissioner, but no allowance was to be made for personal expenses.

Work Undertaken. The Metropolitan Commission as at first constituted extended the work of the Pollution Commission in the following directions:

(1) Analytical investigations of the harbor waters were begun. The object of this work was to ascertain the intensity of sewage pollution in various parts of the harbor and obtain a knowledge of the little understood phenomena of digestion of sewage by these waters. A laboratory was established in the New York Aquarium and a number of analytical experts with boats and other apparatus were employed. This work continued for several months at the end of which time the appropriation of \$10,000 which had been granted to the Commission was exhausted.

(2) Meetings were held with members of the New Jersey State Sewerage Commission looking to co-operation from New Jersey in the studies which New York had undertaken. These negotiations were discontinued after it was found that the State Sewerage Commission was a moribund body and without jurisdiction over a large part of the New Jersey territory.

(3) The Bronx valley sewer project was investigated, and communications, wherein the Commission protested against the discharge of crude sewage into the Hudson river from the Bronx valley district and recommended that

provision be made for purifying this sewage, were addressed to the Bronx Valley Sewerage Commission, the State Engineer and Surveyor, and the State Commissioner of Health.

Soon after the Metropolitan Commission was reorganized a report was sent to the Mayor in which the Commissioners expressed their view of the importance of the work to be done and the time and money required to complete it in accordance with the specifications of the Act of Legislature which had provided for the creation of the Commission in 1906. The reorganized Commission reported on March 16, 1908, that, in their opinion, the objects to be accomplished were important to the people of New York, but that the Commission was without funds and could do little unless more money and time were provided.

Increased Appropriation and Extension of Time. The original legislative Act permitted the city to appropriate \$15,000 for the Commission's use. The reorganized commission found that, of this sum, \$10,000 had been spent and \$5,000 remained to be appropriated by concurrent action of the Board of Estimate and Apportionment and Board of Aldermen. The Commission reported that if the final \$5,000 was appropriated there would be enough funds to meet the outstanding obligations, but there would not be sufficient means with which to complete the work.

It was estimated that the sum necessary to finish the investigation would be \$75,000, and that the time required would be about two years.

Soon after this report was made a legislative bill providing for an additional appropriation and extending the life of the commission to May, 1910, was drafted by the Corporation Counsel and introduced into the Legislature by request of the Mayor. This bill was passed by the Legislature April 23, and is Chapter 422 of the Laws of 1908. It follows:

CHAPTER 422, NEW YORK STATE LAWS OF 1908

An Act to amend chapter six hundred and thirty-nine of the laws of nineteen hundred and six, entitled "An act to provide for a commission to investigate and consider means for protecting the waters of New York bay and vicinity against pollution and authorizing the city of New York to pay the expenses thereof," in relation to the term of said commission, compensation for its members and funds to be raised in said city for the purposes of said act.

Became a law, May 20, 1908, with the approval of the Governor. Passed, three-fifths being present.

Accepted by the City.

The People of the State of New York represented in Senate and Assembly, do enact as follows:

Section 1. Sections five, six and seven of chapter six hundred and thirty-nine of the laws of nineteen hundred and six, entitled "An act to provide for a

commission to investigate and consider means for protecting the waters of New York bay and vicinity against pollution and authorizing the city of New York to pay the expenses thereof," are hereby amended to read respectively as follows:

Sec. 5. The commission shall terminate on May first, nineteen hundred and ten, and all maps, results or surveys and examinations, estimates and other papers and matter acquired by the New York commission shall be properly indexed and labeled and turned over to the board of estimate and apportionment of New York city.

Sec. 6. The members of the commission shall receive a compensation of three thousand dollars per annum for their personal services and expenses.

Sec. 7. Corporate stock of the city of New York may be authorized to be issued by the board of estimate and apportionment without the concurrence or approval of any other board or public body in accordance with section one hundred and sixty-nine of the Greater New York charter, in order to provide the means for carrying out the provisions of this act, but not to exceed the sum of seventy-five thousand dollars in any one year. All payments from the sale of such corporate stock shall be made upon proper vouchers, having the authorization of the chairman and secretary or by the signatures of a majority of the commission herein provided for, and in accordance with the laws, regulations and practice now in force for the payment of money by the comptroller of the city of New York.

Sec. 2. This act shall take effect immediately.

The new Act gave the Board of Estimate and Apportionment power to appropriate, without the concurrence of any other board or public body, \$75,000 a year for the use of the Commission. A single appropriation, which it was estimated by the commissioners would be sufficient to pay for the entire work, was granted by the Board of Estimate and Apportionment June 15, 1908, when \$75,000 was set aside for the use of the Commission.

Unavoidable Delays. Although seriously handicapped by difficulties some of which were apparently unavoidable in the conduct of a temporary commission, especially the necessity of employing the elaborate machinery designed by the City for the administration of its great permanent departments, by delays inseparable from civil service jurisdiction, and by the fact that its period of existence was nearly half gone before a way could be found to pay employees, the work for which the Commission was created has been completed within the period of time and for the sum of money which had originally been estimated by them to be sufficient.

In April, 1908, the Commissioners undertook to meet the obligations of the Commission as at first constituted, including the payment of salaries, office rent, boat hire, etc., by seeking a final appropriation of \$5,000 from the \$15,000 which the Board of Estimate and Apportionment and the Board of Aldermen were authorized by the first legislative Act to set aside for the Commission's use. This undertaking was practically

completed six months later. Delay was caused by the Aldermen in granting the money. The Board of Estimate gave consent to the appropriation at once, but the Board of Aldermen did not concur in the matter until September 29, 1908. No claims against the City on account of the Metropolitan Sewerage Commission are now known to exist.

Payment of Employees. The granting of the appropriation of \$75,000 by the Board of Estimate and Apportionment in June did not at once permit an active prosecution of the Commission's work. It was seven months later before the Commissioners were able to ascertain from the legal department of the City and the courts how they could lawfully employ the assistants required to do the work of investigation and pay their salaries.

Fixing of Salaries. Question as to the right of the Commission to fix the salaries of employees was raised by the Comptroller in a letter which he addressed to the Corporation Counsel under date of August 20, 1908. The Comptroller stated that the money to pay salaries had been duly provided and that a payroll containing the names of three employees had received the required certificate of the Municipal Civil Service Commission, but the salaries of the positions had not been fixed by the Board of Aldermen, as the Comptroller thought perhaps they should be, in accordance with Section 56 of the City Charter. This section provides that the salaries of all City officers paid out of the City treasury shall be fixed by the Board of Aldermen.

Answer to the Comptroller's letter was made by the Corporation Counsel October 26, 1908, to the effect that several members of the Law Department had been considering the question and that they could not agree upon an answer to the question raised. In the opinion of the Corporation Counsel, the correct answer should be left to the determination of the courts.

Upon advice from the Corporation Counsel, the matter was then placed before the courts in an action for a writ of mandamus to compel the Comptroller to pay the salary of one of the employees. This was a test case.

Case of Allen vs. Metz. The case was known as *Allen versus Metz*. Decision was rendered December 29, 1908, by Justice Seabury, Part I, Special Term, Supreme Court. The decision was to the effect that the Metropolitan Sewerage Commission was a State Commission and that the provision of Section 56 of the City Charter, was consequently inapplicable. An order and writ of mandamus were therefore granted by the court and were in due form served upon the Comptroller. The salaries of the Commission's employees were first paid by the Comptroller out of the appropriation of \$75,000 January 11, 1909.

Civil Service Requirements. Question was then raised as to the proper civil service jurisdiction which should be exercised over the Commission's employees. If the Com-

mission was a State board, should its employees be obtained through the State Civil Service Commission or through the Municipal Civil Service Commission? In a communication transmitted to the Metropolitan Sewerage Commission February 1, 1909, the Corporation Counsel expressed the opinion that the employees of the commission should continue to be, as they had been, under the jurisdiction of the Municipal Civil Service Commission. This opinion removed the last obstacle to the employment of the technical and clerical help required and made possible a vigorous prosecution of the Commission's work.

The delay and uncertainty concerning the ability of the Commission to pay the salaries of employees had produced an embarrassing situation. Of the 28 months originally allotted for the completion of the Commission's work, 13 had been lost in ascertaining how the appropriation could lawfully be spent.

The Commissioners had not, however, passed the long delay in idleness. Work had been undertaken and was being prosecuted as rapidly as circumstances permitted. A few faithful employees were attending to duties assigned them with courage and loyalty.

Conclusion of Work Required Under the Act. A preliminary report, embodying the principal findings and recommendations of the Commission was made to the Mayor under date of March 1st, 1910. The present volume is submitted as the full and complete report called for by the legislative Acts under which this Commission has existed.

CHAPTER II

PRESENT AND FUTURE POPULATION OF THE METROPOLITAN DISTRICT AND THE VOLUME OF SEWAGE DISCHARGED INTO NEW YORK HARBOR

POPULATION

Introduction. The object of this study was to forecast as nearly as practicable the future population of the metropolitan district of New York and New Jersey and the distribution of population within the several municipalities and rural districts in that territory. The furthest date for which a forecast could be made which would seem likely to prove reasonably correct appeared to be about 30 years. The estimates were accordingly prepared to cover that period.

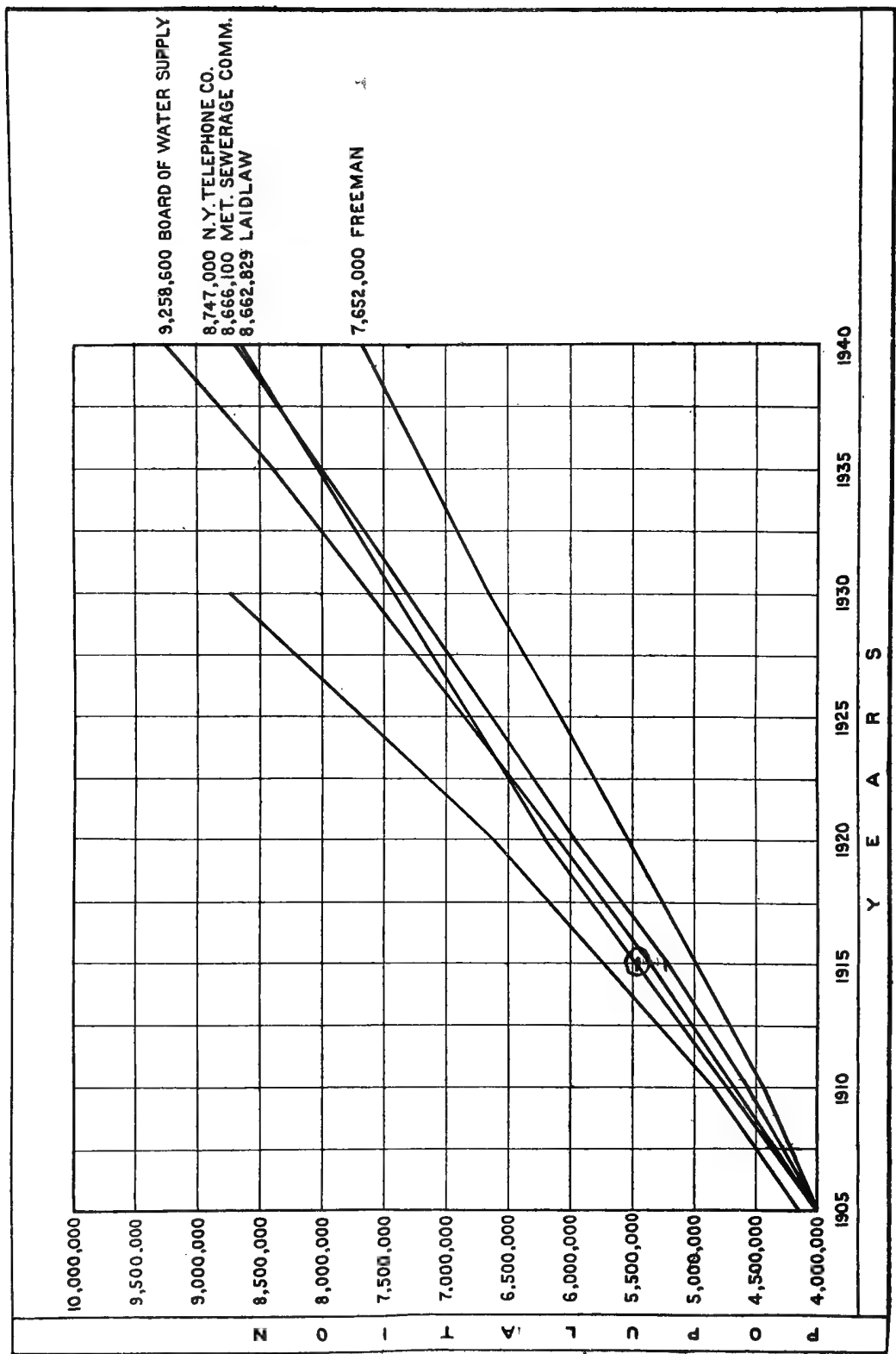
The metropolitan district referred to comprises the whole or part of 84 cities and towns in New York and New Jersey situated within a boundary line fixed in April, 1909, by the Metropolitan Sewerage Commission of New York for the purposes of its investigations. This boundary varies in distance from the New York City Hall between 14 and 28 miles and lies at an average distance of about 20 miles. The limits were drawn so as to include the territory whose drainage flows directly into New York harbor and within which the density of population was such as to make a comprehensive treatment of the sewage problem necessary.

Before making original estimates a study and comparison of the growth of New York and vicinity as forecast by different authorities was made.

Estimates of John R. Freeman Contained in a Report on New York's Water Supply, 1900. Mr. Freeman's figures have proved to be remarkably accurate up to the present time, in spite of the fact that they were made at a time when the last report of a complete census was for the year 1890. Mr. Freeman's detailed estimates for The City of New York for 1905 of 3,980,000 was only one-half of one per cent. below the corrected figure obtained by the actual enumerators of the State.

Added interest attaches to these figures because they are the lowest of all the estimates examined. The author's evident object was to give a conservative opinion concerning the City's growth.

His estimates appear to be based to a considerable extent on the past growth of the city of London, whose increase for the last century has been about 19½ per cent. per



ESTIMATED POPULATIONS OF NEW YORK CITY

decade. A prospective growth of metropolitan New York of from 36 per cent. per decade decreasing to 15 per cent per decade by 1940 has been assumed.

It is possible that Mr. Freeman's estimate for 1940 may prove somewhat low.

Estimates of Dr. Walter Laidlaw Published in "Federation," May, 1908. Dr. Laidlaw's figures for The City of New York are slightly larger than those of Mr. Freeman, his minimum being two and one-half per cent. above what Mr. Freeman terms the greatest probable population.

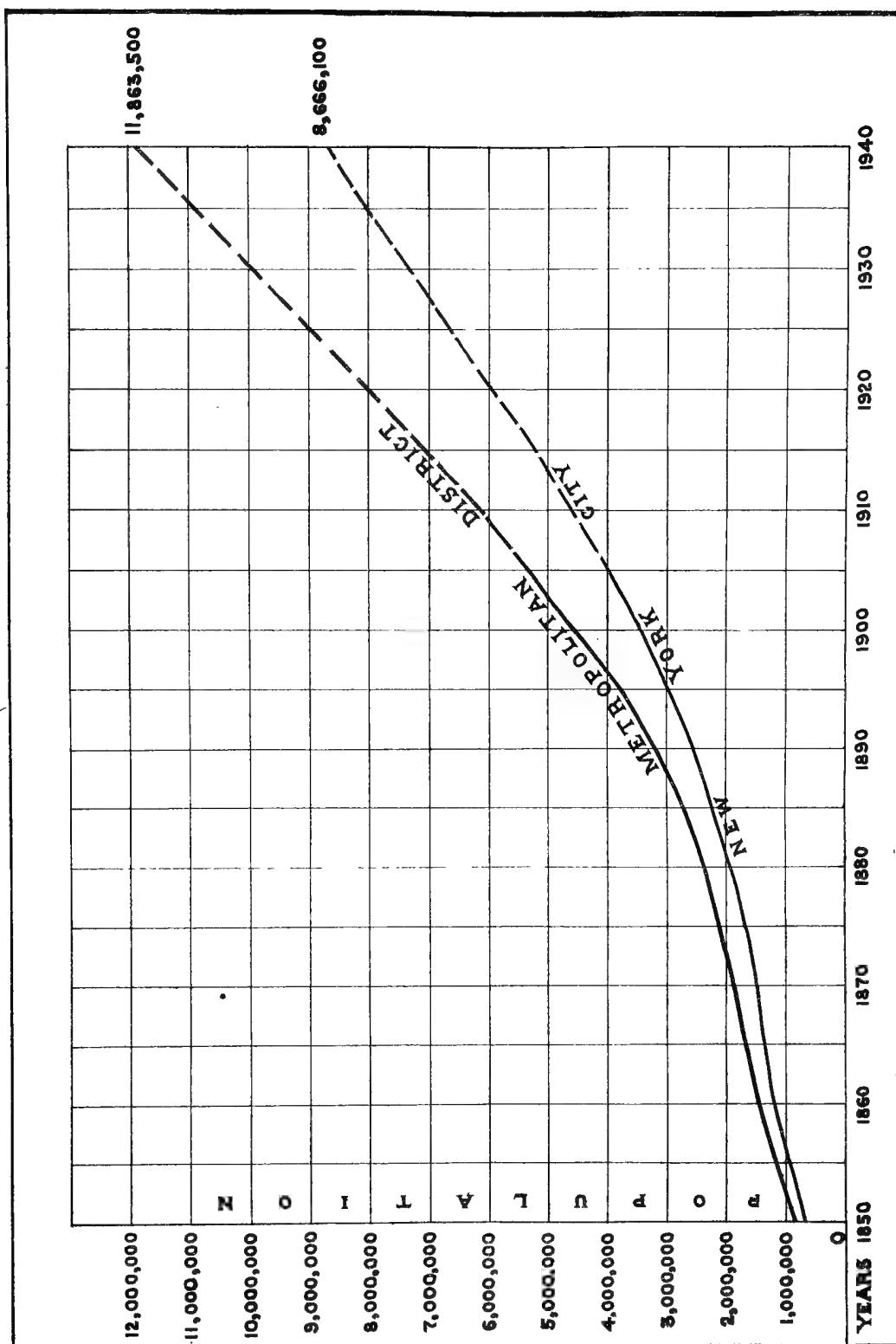
Dr. Laidlaw attaches considerable importance to the relative growth of New York compared with the entire United States, the probable distribution of future immigrants and an increasing trend of population westward due to the development of transportation facilities. From a consideration of these influences he believes that the future increase of the city will be arithmetical, not geometrical; and to get a minimum for 1940 which he also considers the most probable figure, he simply multiplies the increase found for 1900 to 1905 by seven and adds the product to the 1905 population. To get a maximum figure for 1940 he adds to the minimum estimates three and one-half times what he calls the decade surplus, which is twice the increase from 1900 to 1905 over the increase from 1890 to 1900.

Dr. Laidlaw's maximum and minimum figures have been considered conservative by some, but they are the result of 15 years' impartial study of population and are based upon an unusually broad knowledge of the subject.

Estimates of the Board of Water Supply of the City of New York. The Board for an additional water supply for The City of New York has compiled estimates upon a somewhat unique and interesting basis. Manhattan Island is presumed to cease growth after a total of 3,000,000 inhabitants has been reached. The future rate of growth of Brooklyn is based upon the rate which has obtained in Manhattan. The future rate of growth for The Bronx is based upon the rate of growth which obtained in Brooklyn when the latter's transit facilities were at a similar stage of development to those in The Bronx. The rate of growth of Queens is expected to resemble the rate of The Bronx beginning with the opening of transit lines in The Bronx.

Estimates of the New York Telephone Company. The engineers of the New York Telephone Company have estimated future growth by first estimating the future population of the whole country and then projecting into the future the past percentage of this total found in The City of New York and other parts of the metropolitan district, determining last the figures for the smallest subdivisions.

The method followed was similar to that employed by Dr. Laidlaw but assuming a more rapid growth for the United States and a larger proportion of this growth taking place in New York and vicinity. The results are therefore in excess of Dr. Laidlaw's.



POPULATIONS OF THE METROPOLITAN DISTRICT AND NEW YORK CITY

Miscellaneous Estimates for Parts of the Metropolitan District. The report of the Passaic Valley Sewerage Commission for 1908 contains estimates of population for 30 localities within the Passaic valley sewer district for the years 1911 and 1940. Of these places, 15 were divided into from two to 35 sewer districts, each of whose population was, apparently, estimated separately and these were then added together for the whole city or town. The 1911 estimates appear to be based on past growth, but those for 1940 are in most cases so large that they would seem to represent the ultimate population of the district to be provided for in designing the sewers.

The estimates of future population in the Bronx valley sewer district and in the drainage area of the joint outlet sewer of Essex and Union Counties of New Jersey are ultimate figures and do not necessarily represent the populations which may exist in these areas in 1940.

None of the preceding estimates is suitable for use by the Metropolitan Commission: some are not detailed enough; others do not cover the entire territory.

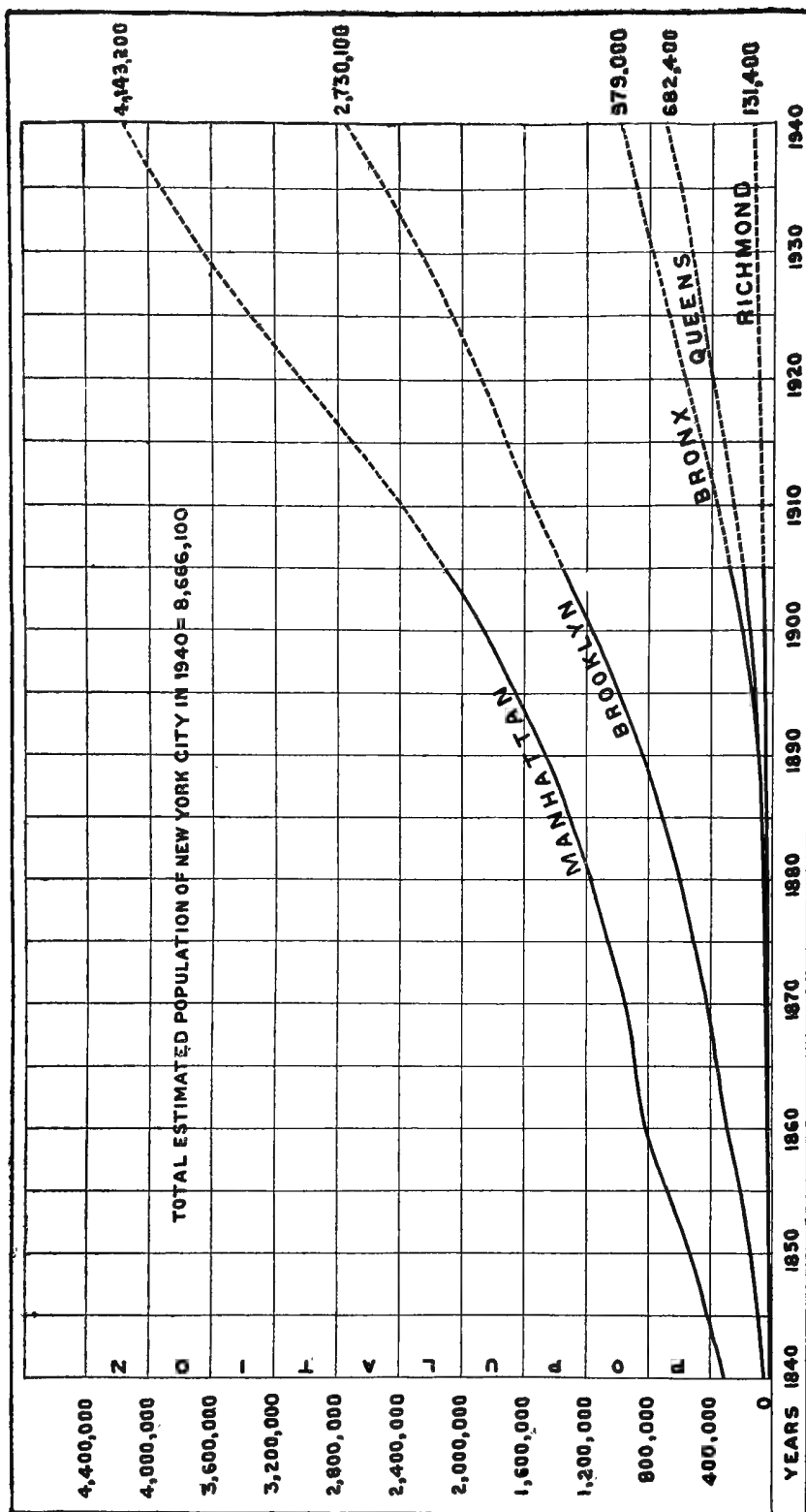
Growth of New York City Compared with that of the Whole Country and of Other Cities. No growth should be assumed which requires too large a percentage of the population of the whole country to be located in New York. Chicago and the 23 cities west of it having over 50,000 inhabitants each in 1900, had, taken altogether, 2,015,208 inhabitants in 1890, while the five boroughs of The City of New York, as at present constituted, had 1,911,689. In the 20 years following 1880 New York gained 1,525,504, while the 24 western cities just mentioned gained 3,078,806.

In other words, the western gain was twice the gain of The City of New York. The cities of the country may be divided into groups, each section containing about the same population as The City of New York in 1880. The first group comprises the four largest cities. The following group the next ten largest and the third group the next 34. In the 20 years from 1880 to 1900 the first and third of these groups grew faster than The City of New York and only the second group grew slower.

Effect of Migration. Migration has always played an important part in the increase in population of New York and is practically certain to do so hereafter. Being the leading port of entry for the United States changes in the population of the whole country, so far as they are affected by immigration from Europe, are reflected with much certainty in the population statistics of New York.

The number of immigrants landed at New York in the past has reached one million in a single year, or about ten times the increase of population; but this high figure does not seem likely to recur.

Movements of population from one part of the metropolitan district to another produce marked variations between the resident and non-resident population. From all



POPULATIONS OF THE BOROUGH OF NEW YORK CITY

points of the compass steam and electric railways bring business people to the commercial centres in the morning and carry them back to the residence sections at night.

Statistics have been furnished the Commission by the various transportation companies showing the passengers brought into Manhattan from outlying territory daily, as follows:

From Long Island	413,500
From New Jersey	203,800
From Staten Island	17,200
From North of The Bronx.....	42,900
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	677,400
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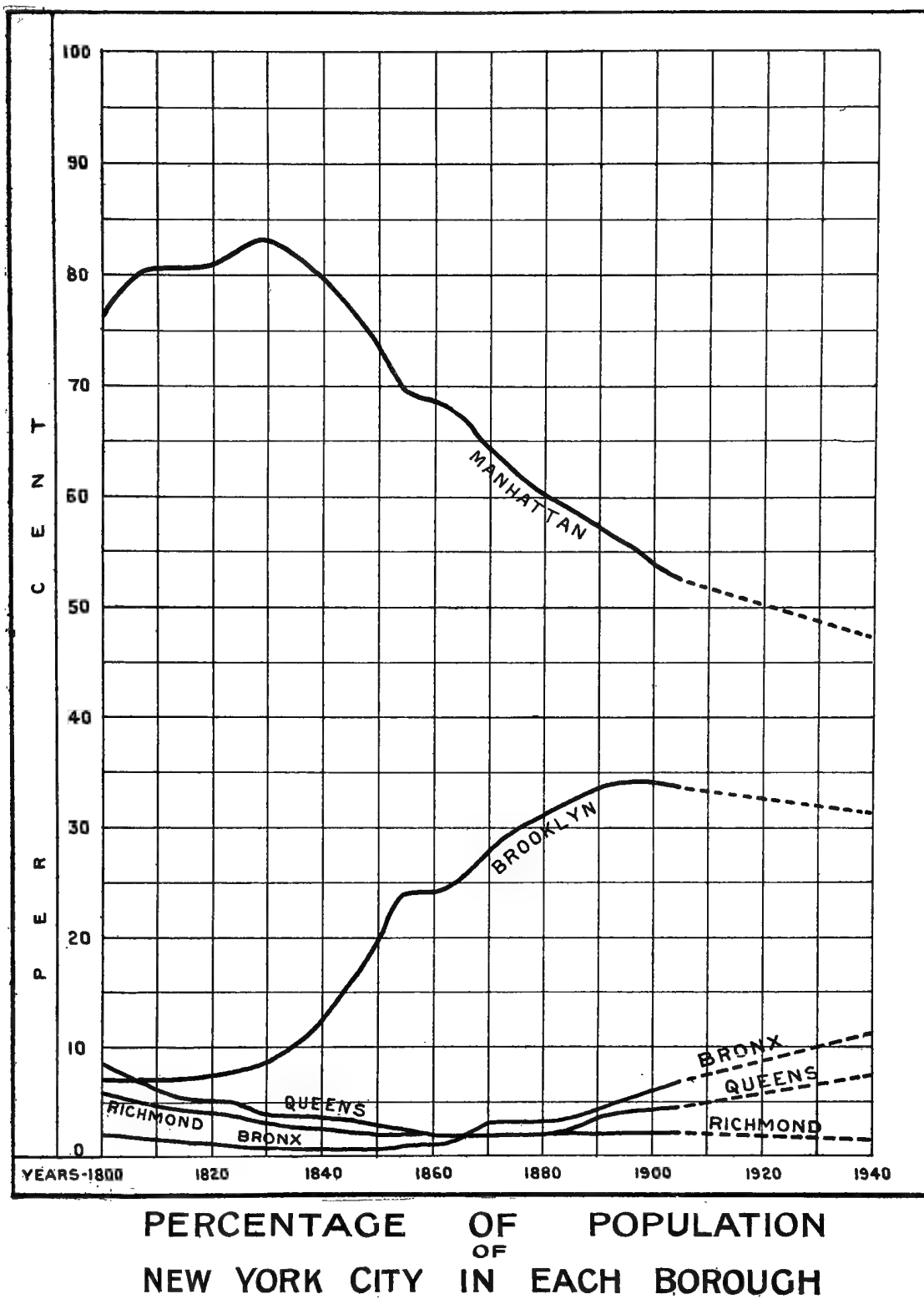
This is seen to add one-third to the resident population of Manhattan daily.

The present increase of transient population is estimated at four per cent. annually.

Possible Reduction of Congestion of Population. A movement against congestion of population exists but it is still of unknown strength. It may in time have a visible effect, though a spreading out of population may not change the total of the metropolitan district, but only tend to distribute people more evenly throughout the district.

Recent rapid transit developments around New York are important to the different localities, but they do not seem likely to materially affect the ratio of the city population to that of the surrounding territory as a whole, as is popularly believed. The electrification of steam lines of railways is going on in all directions in the metropolitan district, and there may be a very rapid accretion of population from this or other causes in particular districts; such, for instance, as in the vicinity of the proposed Jamaica bay improvements and the area directly tributary to the Queensboro Bridge in Long Island City.

Analysis of Previous Estimates. Most of the estimates made by other authorities which were considered in the studies of the Metropolitan Sewerage Commission relate particularly to the growth of The City of New York. A feature of some of the estimates was that no account was taken of the New York and New Jersey State censuses, the results being based wholly, or chiefly, on Federal enumerations. There seems to have been a feeling that the State enumerations were not as carefully made as those of the general government. For the year 1905, however, the New York State census was made under the direction of an expert who later became Chief Statistician for Population of the United States Census Bureau. In the Metropolitan Commission's estimates it has seemed desirable to use the latest State data. In fact, they have been indispensable for about 25 New Jersey towns, for these places have come into existence since the United States Census of 1890.



Methods of Estimating Population Employed by the Metropolitan Sewerage Commission. Preliminary estimates of future population were based mainly on United States Census figures on the ground that, being made on the same basis, they furnished a fair comparison between the growths of municipalities in the two States of New York and New Jersey. State census figures were used for the 20 recently formed New Jersey towns.

Where towns have been formed since the New York and New Jersey State censuses of 1905 were made no estimates were obtainable. Where towns were formed between 1900 and 1905 the future growth of the original undivided area was calculated, after which the percentage for each division of the area as found for 1905 was taken for succeeding five-year periods and was used as the population of each place.

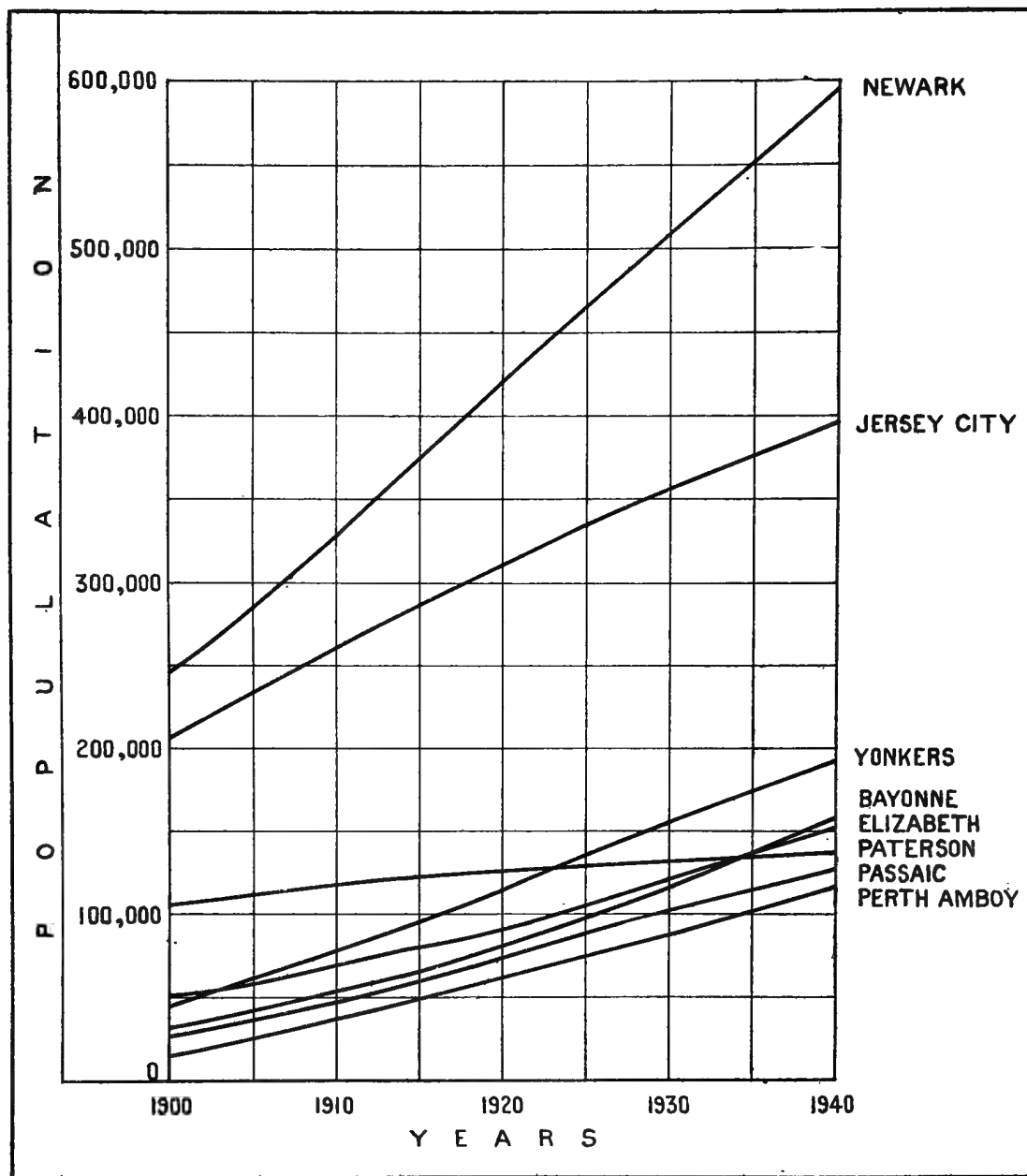
Estimates were first made based upon a geometrical increase—that is, an increase of a uniform percentage—every five or ten years. As growth in a geometrical ratio is not supported by the growth of Manhattan, New York or the metropolitan district in the past, figures for which were obtained and plotted, this method was rejected. Allowing for a gradual decrease in the percentage of annual growth as found in the past, the forecast population for 1940 came so near to that obtained by adopting the arithmetical increase for each five-year interval found for the interval 1900 to 1905, that the revised figures were determined in this way.

It was observed that the average rate of growth of a town bore a certain relation to the density of population. When a certain neighborhood reaches a point where the population will be too dense for that class of neighborhood the rate of increase decreases. In certain parts of Manhattan, indeed, it is probable that there will be no further increase.

The final estimates were based upon the known increases in past years as shown by the census enumerations of the United States Government and the States of New York and New Jersey by projecting into the future rates which have occurred in the past in communities of similar size. The method of applying this was as follows:

The rate of increase was ascertained for towns of different sizes and for assembly districts and wards of different density of population. This was done in order to find the proper percentage of increase to use in each interval of five years for each of the subdivisions (town, ward, etc.) of the metropolitan district. This increase, it was assumed, would be similar for towns of approximately the same size. The results so obtained were plotted and are shown in a graphic way by diagrams which accompany this report, by Table I, and by the following general summary:

Summary of Results. The total population in the metropolitan district in 1905 was 5,332,000. By 1940 it will probably reach 11,800,000.



POPULATIONS OF CERTAIN CITIES
IN
THE METROPOLITAN DISTRICT

POPULATION AND SEWAGE OF METROPOLITAN DISTRICT 143

It is probable that the population of the metropolitan district will increase for the next 30 years as rapidly as if the present population of Indianapolis were added annually.

In 1905 the population of the metropolitan district was equivalent to that of the cities of Chicago, Philadelphia, St. Louis, Boston, Baltimore and Columbus combined, or to that of Paris and Berlin united.

That part of the metropolitan district lying in New York, in 1905 contained 51 per cent. of the entire population of the State.

That part of the metropolitan district lying in New Jersey, in 1905 contained 56 per cent. of the entire population of that State.

The population of The City of New York, which was 4,000,000 in 1905, will probably reach 8,600,000 by 1940.

Outside of The City of New York, but in the metropolitan district of this State, the population in 1905 was 128,000 and will probably reach 400,000 by 1940.

The metropolitan district of New Jersey, including all municipalities, contained 1,200,000 in 1905, and will probably contain 2,800,000 by 1940.

There were, in 1905, ten cities in the metropolitan district of New Jersey having populations in excess of 25,000. By 1940 these will probably contain about 1,900,000 persons. The largest of these ten cities were Newark and Jersey City, whose populations were 283,000 and 232,000 respectively in 1905.

By 1940 there will probably be nine cities in Hudson County, seven towns in Essex County, three in Passaic County and one each in Middlesex and Union Counties, or 21 New Jersey cities having populations of over 25,000. Of these Newark, Jersey City, Bayonne, Paterson, Passaic, Elizabeth and Perth Amboy will have over 100,000 each.

In addition to the resident population of about two and one-fourth millions, Manhattan receives from outside about three-fourths of a million non-residents daily.

TABLE I
SUMMARY OF POPULATION

	1905 *	1940
New York—		
Manhattan	2,102,928	4,143,200
The Bronx	271,592	979,000
Brooklyn	1,355,106	2,730,100
Queens	197,838	682,400
Richmond	72,939	131,400
The City of New York	4,000,403	8,666,100
Mt. Vernon	24,930	80,300
New Rochelle	20,387	65,700
Yonkers	61,414	193,500
Part of Westchester County and Nassau County	21,665	69,400
Metropolitan New York, exclusive of City of New York	128,396	408,900
Metropolitan New York	4,128,799	9,075,000
New Jersey—		
Bayonne	42,262	157,000
East Orange	25,175	63,460
Elizabeth	60,509	155,479
Hoboken	65,468	92,500
Jersey City	232,699	396,000
Newark	283,289	597,600
Orange	26,101	37,035
Passaic	37,837	128,500
Paterson	111,529	135,500
Perth Amboy	25,895	117,534
Cities of over 25,000 in 1905	910,764	1,880,608
Metropolitan New Jersey, exclusive of cities of over 25,000 in 1905	292,623	910,792
Metropolitan New Jersey	1,203,387	2,791,400
Metropolitan district	5,332,186	11,866,400

VOLUME OF SEWAGE DISCHARGED INTO NEW YORK HARBOR

The volume of sewage produced in any district depends primarily on the water consumption, including that obtained from wells or other private supplies. In some towns, such as Paterson, these private supplies furnishing artesian water for manufacturing purposes, such as dye works, silk mills, rolling mills, breweries, etc., constitute an important proportion of the total amount of water used. If discharged into the sewers as is customary, it adds to the volume of sewage, although it may not increase the total amount of the organic constituents of the sewage.

Aside from the water supply the flow of sewage may be materially increased by the infiltration of ground water through leaky sewers, or of surface waters through manhole covers. In the case of combined sewers the flow is enormously increased for short periods during storms.

On the other hand the volume of sewage carried by the sewers is diminished, first, by the fact that suburban or rural areas are not provided with sewers, their liquid wastes going either to cesspools or on to the land; second, because in many instances manufacturing wastes are discharged directly to the nearest stream without passing through a sewer; third, by leakage from defective sewers into the soil, and fourth, on account of water used for street sprinkling and street cleaning purposes.

In a combination of towns such as is represented by those of the metropolitan district it is believed a fair general estimate of the volume of sewage may be determined with the following assumptions:

1st. That the infiltration of surface and ground water to some sewers and the water used from private supplies will about offset that lost by leakage or by the *ordinary* direct disposal to streams and by street sprinkling.

2nd. That where an *unusual* discharge directly to streams is made from mills, etc., due allowance be made for this.

3rd. That the run-off directly due to storms be disregarded by assuming the dry-weather flow only of combined sewers.

4th. That districts without sewerage facilities be omitted from consideration.

From these assumptions it follows that for the general purposes of this estimate the volume of sewage may be taken as equivalent to the water supply, corrected for any excessive discharge from other sources, or diversion to other outlets, by mills, etc.

In this way fluctuations due to non-resident population are accounted for without determining the number of people, the water supply being known.

Applying this method to the metropolitan district the figures given in Table II are obtained.

TABLE II
VOLUMES OF SEWAGE PRODUCED IN THE METROPOLITAN DISTRICT

	Million gallons per day	
	1910	1940
New York State—		
Manhattan	343	650
The Bronx	45	195
Brooklyn	160	560
Queens	27	145
Richmond	8	30
The City of New York	583 ¹	1,580.0
Mt. Vernon	3 ²	9.7
New Rochelle	1 ³	3.2
Yonkers	9 ⁴	27.4
Bronx Valley	3 ⁵	9.1
	599	1,629.4
New Jersey—		
Bergen County :		
New Barbadoes (Hackensack)	1.0 ¹	1.4 ¹
Passaic valley sewer district	5.7 ⁶	41.3 ⁶
Balance of Bergen County in metropolitan district .....	.....	3.7 ¹
Union County :		
Elizabeth	6.0 ⁴	21.8 ¹
Rahway	1.0 ¹	.8 ¹
Westfield and Cranford	1.0 ¹	2.0 ¹
Joint outlet sewer	8.0 ⁷	13.9 ¹
Essex County :		
Passaic valley sewer district.		
Newark	52.0 ⁴	93.7 ¹
Orange	4.5 ¹	10.8 ¹
East Orange	4.1 ¹	12.1 ¹
Balance of Passaic valley district in Essex County	14.7 ¹	42.4 ¹

¹ Based on the consumption of water.² Eng. News, Apr. 29, 1909.³ N. Y. State Bd. Hlth., 1907.⁴ U. S. Census Bul. 105, 1907.⁵ Letter G. R. Byrne, Ch. Engr., May 5, 1909.⁶ Rep. Passaic Valley Sewerage Com., 1908.⁷ Letter from Alexander Potter, Nov. 16, 1908.

POPULATION AND SEWAGE OF METROPOLITAN DISTRICT 147

TABLE II—*Continued*

	Million gallons per day.	
	1910	1940
New Jersey—		
Hudson County :		
Jersey City	39 ³	54.4 ³
Hoboken	8 ³	12.9 ³
Bayonne	4.3 ²	22.0 ³
West Hoboken	1 ³	13.4 ²
Union	2 ³	5.1 ³
North Bergen	1.5 ²	3.1 ³
Weehawken	1 ²	5.7 ²
West New York	1 ²	3.4 ³
Passaic valley sewer district.		
Kearney	1.9 ¹	12.8 ¹
Harrison	1.8 ¹	8.3 ¹
East Newark .....	.6 ¹	1.2 ¹
Miscellaneous .....	.....	3.3 ¹
Middlesex County :		
Perth Amboy	3.5 ²	14.0 ³
Woodbridge .....	.....	1.7 ³
Passaic County :		
Passaic valley sewer district.		
Paterson	31 ³	64.8 ¹
Passaic	4 ³	28.1 ¹
Balance of Passaic valley sewer district in Passaic County	4.4 ¹	17.1 ¹
	203.0	515.2
Total for Metropolitan District	741.0	2,144.6

¹ Rep. Passaic Valley Sewerage Com., 1908.

² Based on the consumption of water.

³ U. S. Census, Bul. 105, 1907.

CHAPTER III

TIDAL PHENOMENA IN THE METROPOLITAN DISTRICT

SECTION I

PRINCIPAL PHYSICAL AND HYDRAULIC FEATURES

GENERAL CONDITIONS

Introduction. The intimate relation between tidal currents in New York harbor and the dispersion and digestion of sewage discharged therein made a thorough knowledge of these movements necessary.

From the constantly changing conditions of the wind, the relative position of the sun and moon, the flow of land water from the rivers and the consequent underrun of sea water upstream, all of which affect to a material degree the tidal movements, it is evident that these movements are complicated and their prediction subject to uncertainty.

In order to obtain as much knowledge of the tidal phenomena as possible the Metropolitan Sewage Commission addressed a letter to the Superintendent of the United States Coast and Geodetic Survey, June 19, 1908, requesting information on the specific points contained in the following questions:

1. What is the volume of water discharged through the Narrows in each direction at each tide under conditions which are (a) usual and (b) unfavorable to a large net outflow toward the sea?
2. What are the principal current phenomena, at the Narrows and at other points in the harbor, which accompany this discharge?
3. What is the volume of water discharged in each direction at each tide at controlling points in the harbor, notably the mouth of the Hudson river, the East river, the Harlem river, Kill van Kull, the Arthur Kill under conditions which are (a) usual, and (b) unfavorable to a large flow toward the sea?
4. What are the main tidal phenomena of the Passaic river, Gowanus canal, Newtown creek, Bronx river, Rahway river, Jamaica bay, Shrewsbury river and Raritan river?
5. Is there a discharge of water through the East river and New York bay from Long Island Sound to the sea, and if so, how great is it under (a) usual conditions and (b) conditions which are unfavorable to the discharge of water from the harbor?
6. To what extent have changes in depth, width and location of channels and the construction of islands and bulkheads affected the flow of water through the harbor?

7. In general terms, what are the controlling factors which affect the flow of water in and out of New York harbor? Especially what is the effect produced by the wind?

8. Would it be feasible to establish a system of gauges in and about New York which would permit the City to make a calculation any time of the quantities of water being carried in the main tidal currents?

9. What are the average, the maximum and minimum velocities in each direction of the currents at the principal points in New York harbor taken at the time when each current is strongest. That is, how do the velocities vary with different tides through the year?

10. What is the distance that water moves in different parts of the harbor through a complete tide from high water to high water and from low water to low water, as shown by floats, and what is the net movement of the water starting from different points toward the sea?

The work of answering these questions as fully and conclusively as desired involved the collation and digestion of much unpublished material in the hands of the Survey. The work was at once undertaken and the answers were sent to the Commission on the 14th of August, 1908.

This study brought out facts regarding the flow of the East river of great practical importance in the investigations of the Commission. It furnished the basis of further theoretical studies and supplementary field work by the Commission to confirm the opinions already formed and to provide additional information.

The tidal phenomena described in the following pages are based upon mean conditions of tidal range and flow. To correct observed velocities these are to be multiplied by the ratio of the mean range of the tide to the range on the day in question.

The Flow of Land Water into the Harbor. The United States Coast and Geodetic Survey has computed the amount of the flow of land water into the harbor from figures obtained from the gauging stations of the United States Geological Survey and from the New York State Engineer and Surveyor. Estimates for those drainage basins on which there were no gauging stations were made on the assumption that the discharge would be proportional to the areas drained and to the rainfall on these areas.

The mean annual discharge of land water into the harbor above the Narrows is 26,442 cubic feet per second or 2,284,588,800 cubic feet per day. See Table I.

The Volumes of Water in the Harbor. For the upper bay, Newark bay, and East river between East 88th Street, Manhattan, and Throgs Neck, the volumes were determined by dividing the areas into squares, ascertaining the average depths as given on the Government chart for each square or fraction of a square and taking the areas of the volumes thus found. For the rivers and kills, information on the Government large scale charts furnished data for cross-sectional areas and from these areas and the distances between the volumes were calculated.

TABLE I

AVERAGE DISCHARGE OF LAND WATER IN CUBIC FEET PER SECOND THROUGH NEW YORK HARBOR

Contributing basin	Area in Sq. Mi.	January	February	March	April	May	June	July	August	Sept.	October	Nov.	Dec.	Mean
Hudson river (above Battery place)...	13,369	18,136	14,203	51,410	53,271	27,537	22,365	14,346	12,809	14,566	20,264	18,751	24,110	24,314
East river, between Governors Island and Randall Island.....	36	57	44	160	165	85	70	44	40	46	63	58	75	76
Newark bay and Kill van Kull, allow- ing 83.66 per cent. for the propor- tion from Newark bay flowing through the Kill van Kull.....	963	1,472	1,153	4,175	4,326	2,235	1,815	1,165	1,040	1,183	1,646	1,522	1,958	1,974
Upper bay (exclusive of all above tributaries).....	37	58	46	165	171	89	72	46	41	47	66	61	78	78
Total entering Upper bay above the Narrows	14,395	19,723	15,446	55,910	57,933	29,946	24,322	15,601	13,930	15,842	22,039	20,392	20,221	26,442
Arthur Kill, allowing 16.34 per cent. for proportion from Newark bay	353	552	432	1,563	1,620	838	681	437	389	443	615	569	733	739
Raritan river.....	1,105	1,669	1,397	4,731	4,902	2,534	2,058	1,320	1,178	1,340	1,864	1,726	2,219	2,237
*Total entering Lower bay, exclusive of that entering Upper bay.....	1,458	2,221	1,829	6,284	6,522	3,372	2,739	1,757	1,507	1,783	2,479	2,295	2,952	2,976

Note. Of the water entering and leaving Newark bay and tributaries 83.66 per cent. passes the Kill van Kull and 16.34 per cent. passes the upper end of Arthur Kill.

Annual Rainfall:—

Hudson and Mohawk valleys, above gauging stations..... 37 inches.
Hudson valley below gauging stations..... 41
East river..... 44½
Newark bay..... 44
Upper bay..... 45
Arthur Kill basin..... 45
Raritan river basin..... 43
Total from Arthur Kill, Newark bay, Raritan river, but not Shrewsbury river or similar
drainage areas.....

The shape of the harbor is shown on the various cuts in this report. The areas of the several main divisions of the harbor and an estimate of the quantity of water in each division below the level of mean low water are given in Table II.

TABLE II
HARBOR OF NEW YORK
WATER AREAS, DEPTHS AND VOLUMES OF WATER

Division	Area in Square Miles	Average Depth in Feet	Water Volume Below M. L. W. in Cubic Feet
Upper bay.....	20.74	22.43	12,970,000,000
Hudson river, from the Battery to Mt. St. Vincent.....	14.49	30.70	12,330,000,000
East river, from the Battery to Throgs Neck.....	14.80	27.03	11,160,000,000
Harlem river.....	0.49	13.58	187,700,000
Newark bay.....	8.35	6.63	1,542,000,000
Kill van Kull.....	1.12	23.40	728,000,000
Arthur Kill.....	4.93	12.62	1,735,000,000
Total water surface	64.92		
Total volume of water below mean low water.....	.....	.....	40,652,700,000

Tidal Ranges. The mean range, or rise and fall of the tide is not the same at all points in the harbor; and the hours at which high and low water occur at different points vary considerably. These differences in both range and time sometimes cause the tidal currents to flow in a direction contrary to that which would naturally be expected from the stage of the tide. That is, there are places in the harbor where the flood current continues to run after the water level begins to fall, and where the ebb current continues to run after the water level begins to rise.

These differences are given in Table III.

TABLE III

MEAN RANGE OF TIDE, AND TIMES OF HIGH AND LOW WATER IN NEW YORK HARBOR.*

Station	Tidal Range	Times †		Differences in Times	
	Mean Feet	H. W.	L. W.	H. W.	L. W.
Sandy Hook (Horseshoe)	4.7	7:35	1:27	—0:29	—0:38
Canarsie, Jamaica bay.....	4.2	8:34	2:35	0:30	0:30
Tottenville, Arthur Kill.....	5.6	7:55	1:59	—0:09	—0:06
Shooters Id., Newark bay.....	4.6	8:20	2:28	0:17	0:23
Passaic Light, “ “	4.7	8:41	2:59	0:38	0:54
Fort Hamilton, Narrows.....	4.6	7:41	1:38	—0:23	—0:28
Governors Island.....	4.4	8:04	2:05	0:00	0:00
Blackwells Id. Light	5.3	9:54	3:39	1:50	1:33
Throgs Neck.....	7.3	11:09	5:14	3:05	3:09
Spuyten Duyvil.....	4.0	8:49	2:51	0:45	0:46

* Tide Tables, United States Coast and Geodetic Survey.

† Solar time in hours and minutes after transit of moon.

The Lunar Day. A lunar day is the period between the major transits of the moon, or in other words the interval between consecutive overhead passages of the moon across the meridian. It is similar to a solar day except that it is determined by the position of the moon instead of by that of the sun. A lunar day is longer than a solar day by 50 minutes and 28 seconds. In other words, one lunar hour is equal to 1.03505 solar hours.

When separate tidal waves enter a strait from opposite ends there results in the strait an interference tide, or overlapping of the tidal waves. This does not mean that such a meeting and overlapping results in a superposition of one wave over another, but that the resulting tide is due partly to the influence of each wave. The East river is such a strait.

Interference Tides. Interference tides of this kind occur in New York harbor because separate tidal waves enter, one from the sea, past Sandy Hook, and the other from Long Island Sound, past Throgs Neck. These separate tidal waves are not synchronous, *i. e.*, their periods of high water or low water do not occur at the same time.

The Sound tide entering the East river is traceable as far as Governors Island where, by counteracting and in part neutralizing the tidal wave entering by the Narrows, the resultant range of the tide is less than at either Throgs Neck or Sandy

Hook. It should be said, however, that this diminution of range in the Upper bay is in part attributable to the throttling effect of passing through the East river of the one wave and through the Narrows of the other.

At the southern end of the East river the range is 4.4 feet, while at the other end it is 7.2 feet. Where the higher ranges occur (Throgs Neck) the tidal wave enters 3 hours and 5 minutes later than the tidal wave from the ocean at the other end (Governors Island).

The violent currents at Hell Gate are due to these differences in level, augmented by the difference in the stage of the two tides and their occurrence at a point where the channel is so contracted as to prevent the free flow of water in its effort to restore a uniform elevation of the surface.

EFFECT OF TIDAL RANGE

East River. In the East river the tidal currents are nearly hydraulic, *i. e.*, they flow from the body having temporarily the higher water surface level to the one having temporarily the lower. In other words, the flow is caused by the difference in height which temporarily exists between the bodies connected. In consequence, the velocities in the East river vary very closely as the square root of the range of tide, in accordance with well known laws of hydraulics.

Hudson River. In the Hudson river the tidal currents are due chiefly to the progressive wave motion, as is shown by the fact that the greatest flood and ebb velocities occur at nearly the times of local high and low water. In the Hudson river the velocities vary directly as the range of tide.

The Kills. In the Kill van Kull and in the Arthur Kill the tidal currents are nearly hydraulic, and in them, as in the East river, the velocities vary closely as the square root of the range of tide.

The Narrows. In the Narrows the tidal currents are partly hydraulic and partly due to the progressive wave motion. In consequence, the velocities in the Narrows vary approximately midway between the square root of and directly as the range of tide.

The Harlem. In the Harlem river the tidal currents are nearly hydraulic, and are due to a temporary difference in water level between the East river and the Hudson river. In the Harlem river the velocities vary approximately as the square root of the range of the tide. The velocities of the current are variable and depend on the conditions existing at the times of observation.

Strength of Current. The strength of a tidal current is that which obtains when the velocity is a maximum. The strength of the current at the surface does not bear

a constant relation to the mean strength of the current for any particular section of the channel. There is an average relationship between the surface and mean strengths of the current for each part of the harbor under normal conditions, but this is affected:

1. By the underrun;
2. By the inertia of the moving mass of water, and
3. By the reversal of the tidal current which takes place at different parts of the same cross section at different times.

Current Velocities. Velocities that may be expected at or just below the surface under normal conditions when the tidal currents are flowing at a maximum and the mean velocities for the entire duration of a tide are given in Table IV.

TABLE IV
VELOCITIES IN KNOTS PER HOUR IN NEW YORK HARBOR

	At Strength		Mean for Tide	
	Ebb	Flood	Ebb	Flood
Hudson river, off 39th street.....	3.0	2.0	1.86	1.27
East river, Brooklyn Bridge.....	3.8	3.6	2.42	2.22
East river, 11th street.....	3.0	2.9	2.00	1.98
East river, 19th street.....	2.6	2.3	1.99	1.81
East river, 31st street.....	2.9	2.6	1.90	1.73
Kill van Kull, Port Richmond.....	2.2	1.8	1.48	1.24
Kill van Kull, Bergen Point.....	2.0	1.8	1.17	1.04
Harlem river, 144th street.....	1.0	1.0	0.71	0.69
Harlem river, High Bridge.....	1.9	1.8	1.30	1.22
The Narrows.....	2.0	1.6	1.22	0.95

These velocities were obtained from the records of the Coast and Geodetic Survey and from the float observations made by the Metropolitan Sewerage Commission.

Tidal Prisms. The tidal prism of a body of water is that part which lies above the level of mean low tide at the time of high tide. In other words, it is the volume of water that flows in from below between low tide and high tide.

The ratio of the tidal prisms to the water lying below mean water level is given in Table V.

TABLE V

RATIO OF TIDAL PRISMS TO WATER VOLUMES IN NEW YORK HARBOR

Division of Harbor	Area Square Miles	Average Depth Feet	Average Tide Range Feet	Volume below M. L. W. Cubic Feet*	Tidal Prism Cubic Feet*	Percentage
Upper bay.....	20.74	22.4	4.4	12970.	2,541.	19.6
Hudson river, Battery to Mt. St. Vincent.....	14.49	30.7	4.2	12330.	1,697.	13.7
East river, Battery to East 88th. street	3.31	29.2	4.7	2700.	434.	16.1
East river, East 88th. street to Old Ferry Point...	8.98	22.3	6.2	5590.	1,552.	27.8
East river, Old Ferry Point to Throgs Neck	2.51	41.0	7.1	2870.	497.	17.3
Harlem river.....	0.49	13.6	5.3	185.7	72.5	39.0
Newark bay.....	8.35	6.6	4.6	1542.	1,071.	69.6
Kill van Kull.....	1.12	23.4	4.8	728.	149.8	20.6
Arthur Kill.....	4.93	12.6	5.4	1735.	743.	42.8

* In millions of cubic feet.

For equal ranges of tide the percentage will increase inversely as the average depth; therefore, the shallower the water the greater will be the ratio of change of volume during each tide. The least ratio of change is in the Hudson river, and the greatest in Newark bay.

SECTION II

PRINCIPAL CURRENT PHENOMENA

IN THE NARROWS AND AT OTHER POINTS IN THE HARBOR

Inertia is that property of matter which causes a body to remain in a condition of rest or motion. When the tidal currents turn from flood to ebb or from ebb to flood, the inertia of the moving stream plays a very important part. The turn of the tide takes place first along the shore. In the Narrows the first change of current appears on the east side of the channel.

As the specific gravity of the sea outside of New York bar is about 1.024, the sea water is approximately $2\frac{1}{2}$ per cent. heavier than the land water discharged from the rivers. As the tide turns there is a tendency for this lighter land water to flow out over the top of the incoming heavier salt water.

Underrun. There also results an incoming flow of sea water at or near the bottom, already described as the underrun. The reversal in direction of the surface current ordinarily takes place in the shallower waters near the shore, where it is less influenced by the inertia of the greater volume flowing in the channel.

The underrun of sea water up the Hudson river extends at times as far as Carthage,* 64 miles above the Battery, brackish water having been observed as far as Poughkeepsie, 75 miles from the Battery.†

Tidal Velocities. Pure tidal motion is harmonic in character, *i. e.*, the velocities caused by a tidal wave are rhythmic, varying in degree by regular periods. The velocity at any part of the tide is proportional to the sine of an arc representing the time elapsed since slack water, in which the entire circle represents a complete cycle of the tide, or 12 lunar hours, one lunar hour being represented, therefore, by 30 degrees of arc. Variations from this law occur, however, from the following causes:

1. The underrun at the times of tidal change.
2. The currents are not always in the same direction as the channel currents.
3. The inertia of the flowing stream at the time when it would otherwise reverse its direction from flood to ebb or *vice versa*.
4. The effect of wind.
5. Variation in the volume of land water brought down the rivers from drainage areas above.

Paths of Floating Bodies. In consequence of these causes, it is not possible to predict with great accuracy the path which will be followed by a floating particle. It is possible, however, to predict the path if the conditions stay approximately normal, as follows:

Suppose a particle to be set adrift at a point where the maximum velocity or "strength" of the tidal current is known. Then, according to the law of sines, the velocity of the current at any time would be

$$A.\cosine\ 30\ t$$

in which A denotes the velocity of the tidal current at time of strength and t the number of lunar hours after the time of strength. If solar hours are used, then the velocity at any time would be

$$A.\cosine\ 29.98\ t$$

By computing and plotting a number of these velocities at different stations in the locality it is possible to predict the motion that would normally be taken by a floating particle carried along by the current.

Owing to the variation in channel sections and directions which cause side currents or eddies, it is not safe to calculate the predicted course which a floating particle will take. It is safer to rely upon observations made with floats, many of which were made by the Metropolitan Sewerage Commission.

*Rep. U. S. C. & G. S. 1887 App. 15 p.304.

†Rep. Com. on Add. Water Sup. N. Y. 1903 p. 523.

In this connection it must be remembered that surface velocities do not ordinarily indicate the mean velocities of tidal streams. While the surface particles may have a known velocity in one direction the velocity of the particles beneath the surface often differ materially.

To determine accurately the mean velocity of a tidal current, it would be necessary to take simultaneous observations at many points across a stream and at many points in depth below the surface. These observations should cover a considerable period of time in order to obtain fair averages. Owing to the expense involved, which would be very great, and to the obstruction of the waterway by anchoring observing boats at close intervals across the stream, this method was not undertaken by the Metropolitan Sewerage Commission.

THE CURRENTS WHICH EXIST IN THE HARBOR AT EACH LUNAR HOUR OF A TIDAL CYCLE

As shown by the Metropolitan Sewerage Commissions' float experiments and by a study of the currents, the hourly conditions are as follows:

I Lunar Hour. The water is flowing out of the Upper bay through the Narrows, toward the sea; into the Upper bay through the Kill van Kull, the East river and the Hudson river; and the water level in the Upper bay is falling.

II Lunar Hour. The water is flowing out of the Upper bay, through the Narrows, toward the sea, flowing into the Upper bay through the Kill van Kull, East river and Hudson river; and the water in the Upper bay is rising.

III Lunar Hour. The water is flowing out of the Upper bay, through the Narrows, toward the sea; flowing into the Upper bay through the East river and the Hudson river; the Kill van Kull is nearly slack; and the water in the Upper bay is rising.

IV Lunar Hour. The water is flowing into the Upper bay, through the Narrows,* from the sea; into the Upper bay from the Hudson river; out of the Upper bay and Hudson river into the East river; out of the Upper bay into the Kill van Kull; and the water in the bay is rising.

V Lunar Hour. The water is flowing into the Upper bay, through the Narrows, from the sea; the Hudson river is nearly slack; flowing out of the Upper bay through the East river and the Kill van Kull; and the water in the bay is rising.

VI Lunar Hour. The water is flowing into the Upper bay, through the Narrows, from the sea; out of the Upper bay through the Hudson river, East river and Kill van Kull; and the water in the bay is rising.

*In the Narrows the surface currents are nearly slack.



Surface Currents as Shown by Floats, First Lunar Hour



Surface Currents as Shown by Floats Second Lunar Hour



Surface Currents as Shown by Floats, Third Lunar Hour



Surface Currents as Shown by Floats, Fourth Lunar Hour



Surface Currents as Shown by Floats, Fifth Lunar Hour



Surface Currents as Shown by Floats, Sixth Lunar Hour



Surface Currents as Shown by Floats, Seventh Lunar Hour



Surface Currents as Shown by Floats, Eighth Lunar Hour



Surface Currents as Shown by Floats, Ninth Lunar Hour



Surface Currents as Shown by Floats, Eleventh Lunar Hour



Surface Currents as Shown by Floats, Twelfth Lunar Hour

VII Lunar Hour. The water is flowing into the Upper bay, through the Narrows from the sea; flowing out of the Upper bay through the Hudson river, East river and Kill van Kull; and the water in the bay is rising.

VIII Lunar Hour. The water is flowing into the Upper bay, through the Narrows, from the sea; flowing out of the Upper bay through the Hudson river, East river and Kill van Kull; and the water in the bay is falling.

IX Lunar Hour. The water is flowing into the Upper bay, through the Narrows, from the sea, and through the Kill van Kull; flowing out of the Upper bay through the Hudson river and the East river; and the water in the bay is falling.

X Lunar Hour. The water is flowing out of the Upper bay, through the Narrows, toward the sea; out of the Upper bay and East river through the Hudson River; into the Upper bay and Hudson river through the East river; into the Upper bay through the Kill van Kull; and the water in the bay is falling.

XI Lunar Hour. The water is flowing out of the Upper bay, through the Narrows, toward the sea; into the Upper bay through the Hudson river, East river and Kill van Kull; and the water in the bay is falling.

XII Lunar Hour. The water is flowing out of the Upper bay, through the Narrows, toward the sea; into the Upper bay through the Hudson river, East river and Kill van Kull; and the water in the bay is falling.

PRINCIPAL TIDAL PHENOMENA IN THE ESTUARIES OF THE HARBOR

Tidal Rivers. The Passaic river, Newtown creek, Bronx river, Rahway river and Raritan river are imperfect examples of tidal rivers with estuaries. In such rivers there is a tendency for the maximum flood velocity to occur less than three hours before the time of local low water. In such streams the range of tide may increase somewhat in going upstream, provided the cross section diminishes gradually, but if piers or bridges interfere seriously with the flow the range of tide above such obstructions will be decreased.

Jamaica Bay. Jamaica bay is a tidal basin connected with the ocean through Rockaway inlet. The tidal currents through this inlet are hydraulic and, therefore, their greatest velocities occur when the bay is being filled or emptied most rapidly, or about three hours before high or low water in the bay. As the area of Jamaica bay and its tidal tributaries is about 25.1 $\frac{1}{4}$ * square statute miles, the tidal currents through the inlet will be strong, and the resulting erosion the cause of the great depth of water just west of Rockaway Beach.

*Rep. Jamaica Bay Improvement Com., 1909, p. 33

Shrewsbury River. In the Shrewsbury river the range of tide in the broad portion is considerably smaller than the range around Sandy Hook on account of the narrow connecting water-way. If this water-way were made deeper, a greater rise and fall of the water would be caused in the broad portion of the river, and the tidal volume entering and leaving the river would be increased. A deepening of the water-way would accelerate the times of the occurrences of the tides.

Gowanus Canal. Gowanus canal is so situated that the tidal flow must be very small, since the volume of water which enters upon a flood tide or leaves upon an ebb tide will be the area of the canal multiplied by the range of tide. At the head of the canal, or at the head of any of its branches, the velocity from the tide is practically zero.

Newtown Creek. Newtown creek is similar to Gowanus canal, and the same phenomena exist in the former as in the latter.

SECTION III

PHENOMENA OF DISCHARGE

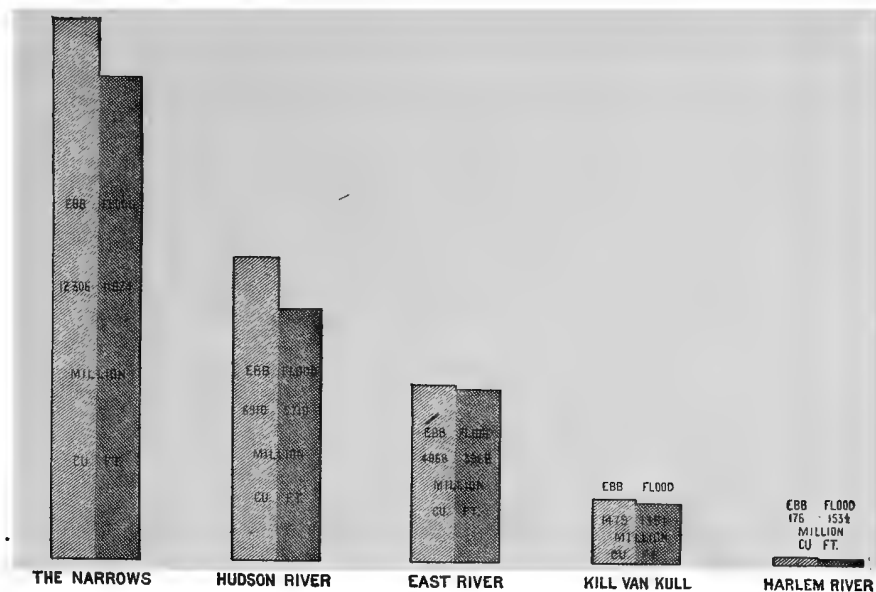
VOLUMES OF DISCHARGE

The volume of water discharged on each tidal current can be estimated in accordance with the principles deduced for calculating the flow of rivers. The estimates will be approximately correct; and, considering the daily variations, will be sufficiently accurate for all practical purposes. These estimates are based on the area of a selected section below the mean level of the water surface, the mean velocity of the current and the time during which the current flows.

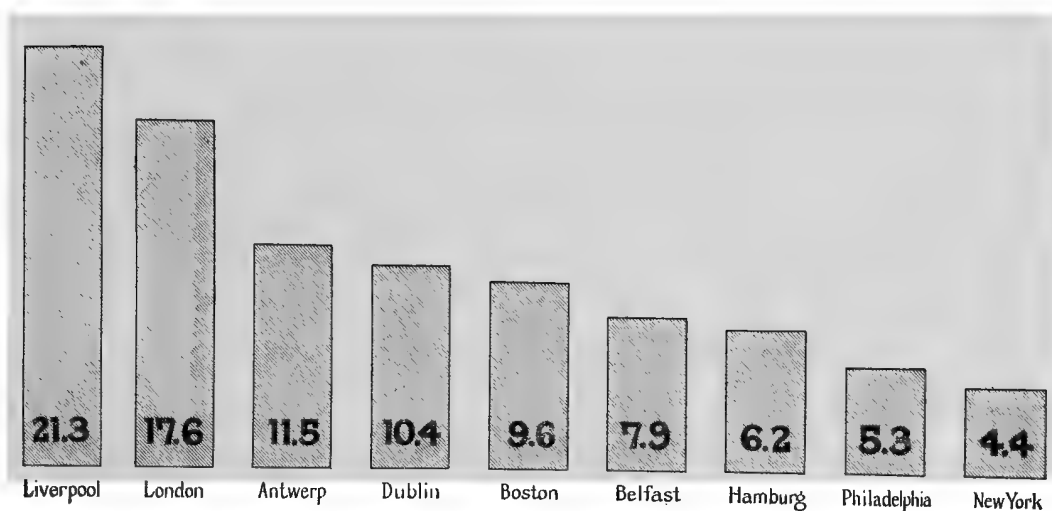
The volume of water discharged on the ebb currents exceeds that on the flood currents, so that there is a resultant flow during each tidal period through the harbor toward the sea. Under conditions of minimum net outflow toward the sea this resultant is about one-half of that under normal conditions.

The Narrows. By ebb flow is meant the southerly flow toward the sea; and by flood the northerly flow into the Upper bay.

The Commission has estimated the average of the ebb and flood flows through the Narrows, and obtained 11,665 million cubic feet per six lunar hours. The resultant flow, or the excess of ebb over flood, is the land-water from the drainage areas above the Narrows and the excess of flow through the East river from the Sound. The land water is 1,182.3 million cubic feet and the resultant through the East river may be taken as 100 million cubic feet per tidal cycle, or a total of 1282.3 million cubic feet.



VOLUMES OF WATER FLOWING INTO AND OUT OF NEW YORK HARBOR EACH TIDE



RISE AND FALL OF TIDE IN VARIOUS HARBORS

Liverpool	21.3 feet	Boston	9.6 feet
London (London Bridge)	17.6 "	Belfast	7.9 "
Antwerp	11.5 "	Hamburg	6.2 "
Dublin	10.4 "	Philadelphia	5.3 "
New York	4.4 feet.		

Therefore, the estimate is:

For Ebb.....	12,306,150,000 cubic feet
For Flood.....	11,023,850,000 “ “
Excess or Resultant.....	1,282,300,000 “ “

The Coast and Geodetic Survey estimated the average of ebb and flood flows at 11,613 million cubic feet, on the basis of a maximum surface velocity of 2 knots per hour. They also made a computation on the basis of tidal volumes and land water discharges, neglecting the resultant flow of the East river as being too small to effect a material difference and obtained the following:

For Ebb.....	12,213,029,000 cubic feet
For Flood.....	11,030,695,000 “ “
Excess or Resultant.....	1,182,334,000 “ “

Both these estimates are based on the same fundamental data, which accounts for the closeness of the results.

Hudson River. By ebb flow is meant the southerly flow into the Upper bay; and by flood the northerly flow from the Upper bay.

The Commission has estimated the volumes discharged per tidal cycle past a section opposite West Thirty-ninth street, Manhattan, and obtained:

For Ebb.....	6,910,000,000 cubic feet
For Flood.....	5,740,000,000 “ “
Excess or Resultant.....	1,170,000,000 “ “

The Coast and Geodetic Survey estimated the average of ebb and flood flows past a section between Battery place and Communipaw ferry at 6,166 million cubic feet; and computed the flows on the basis of tidal and non-tidal discharges, with the following results:

For Ebb.....	6,722,246,000 cubic feet
For Flood.....	5,635,070,000 “ “
Excess or Resultant.....	1,087,176,000 “ “

East River. The East river, so called, is a strait, not a river, connecting Upper New York bay and Long Island Sound. Tidal waves enter at both ends, the Sound wave being approximately twice as high as the bay wave. There is a decided interference of these waves traceable to the southerly end of Blackwells Island.

The two tides ordinarily meet at a point between Throgs Neck and Stepping Stones Light, so that, strictly speaking, the flood (or ebb) currents on each side of this meeting point flow in opposite directions. The ebb current may therefore be considered as flowing the entire length of the East river from Throgs Neck to the Battery and a flood current as flowing from the Battery to Throgs Neck.

The tidal currents in the river are peculiar. During flood currents there is a tendency for the surface water to flow from the channel towards the shores, which is es-

pecially noticeable along the lower reaches of the river. The opposite tendency is noted during ebb currents. This tendency appears to be created by the higher velocity in the channel over that along the bulkheads. The currents along the bulkheads are restricted by the fractional resistance of the docks, walls and irregularities so that during flood currents the water surface along the bulkheads does not rise as rapidly as that in mid-stream. During ebb currents there is a tendency to produce a reversal of these conditions. This tendency was made apparent by the action of the dyes* which were put into the waters and by the floats* working their way into the slips during the flood and out during the ebb.

Floats set adrift near Throgs Neck had a tendency to work their way into the Sound, while from Hell Gate the general tendency of the drift was southerly, passing into the Upper bay either by way of Buttermilk channel or, in some cases, to the west of Governors Island. One float (No. 65) set adrift off College Point continued for over three days to oscillate between Whitestone Point and Brooklyn Bridge, and never left the limits of the East river. It was finally taken out near North Brother Island.

Although the ranges of the tide at the Battery and at Throgs Neck are different and occur at different times, the slopes of the surface in both directions are equal. There is not a great difference in the observed velocities between the flood and ebb currents but there is probably a greater velocity on the flood current east of Hell Gate and a greater velocity on the ebb current south of Blackwells Island;† but as the average cross sectional area of the stream is greater during the ebb east of Hell Gate and on the flood south of that point, it is the opinion of the Coast and Geodetic Survey that the net or resultant flow from the Sound into the Upper bay is small, and that under normal conditions the volume transmitted during the ebb current could not be more than one or two per cent. greater than the volume transmitted during the flood current. The Survey estimates that the average of the ebb and flood volumes is 4,028 million cubic feet for each six lunar hours.

The Commission has estimated the volumes discharged past sections between Brooklyn Bridge and East Thirty-first street, Manhattan, principally using the float observations made by the Metropolitan Sewerage Commission, and obtained the average for the ebb and flood volumes as 4,018 million cubic feet for each six lunar hours. These calculations showed an excess of ebb over flood of about 12 per cent. of the average volume transmitted. As surface velocities were considered, and as there are not sufficient observations of velocities below the surface to make it clear what the mean velocity really is, it is probable that this average resultant flow is too great.

* Experiments of Metropolitan Sewerage Commission.

† Letter of O. H. Tittman, Supt. U. S. C. & G. S. Feb. 6, 1909.

Taking the larger of the Survey estimates, namely, two per cent., the resultant flow would be 80 million cubic feet. In order to be conservative for the purposes of this investigation, and give the river as great a resultant flow as is consistent with the evidence, a net or resultant flow from the Sound into the Upper bay of 100 million cubic feet for each tidal cycle of 12 lunar hours has been assumed. The results, therefore, are:—

For Ebb.....	4,068,000,000 cubic feet
For Flood.....	3,968,000,000 “ “
Excess or Resultant.....	100,000,000 “ “

Kill van Kull and Arthur Kill. The Kill van Kull is a strait joining the Upper bay with Newark bay, and the Arthur Kill is a strait joining Raritan bay and the Lower bay with Newark bay.

As the water falls in Newark bay the ebb current flows through the Kill van Kull into the Upper bay and through the Arthur Kill into the Lower bay. As the water rises in Newark bay the flood current flows through the Kill van Kull from the Upper bay and through the Arthur Kill from the Lower bay.

The Coast and Geodetic Survey estimates that of the waters entering and leaving Newark bay and tributaries, about 84 per cent. passes through the Kill van Kull and 16 per cent. passes through the Arthur Kill.

The Survey estimated the volumes of flow through the Kill van Kull and Arthur Kill by computing the volume of the tidal prism in Newark bay and its tributaries, and then dividing this flow in the ratio of the percentages just given.

The results thus obtained are averages of ebb and flood volumes transmitted during six lunar hours, and are:

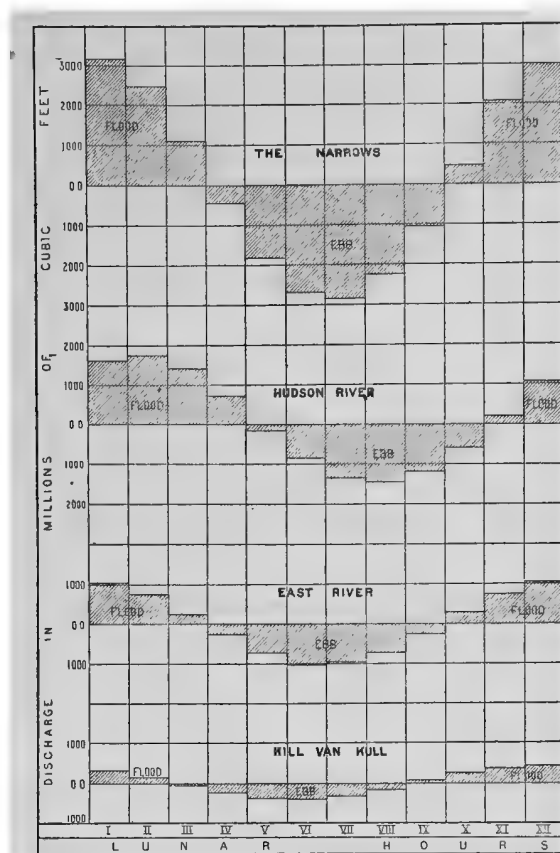
For Kill van Kull.....	1,600,000,000 cubic feet
For Arthur Kill.....	319,000,000 “ “

The Survey also made a computation on the basis of tidal and non-tidal discharges, which, for the Kill van Kull gives the following results:

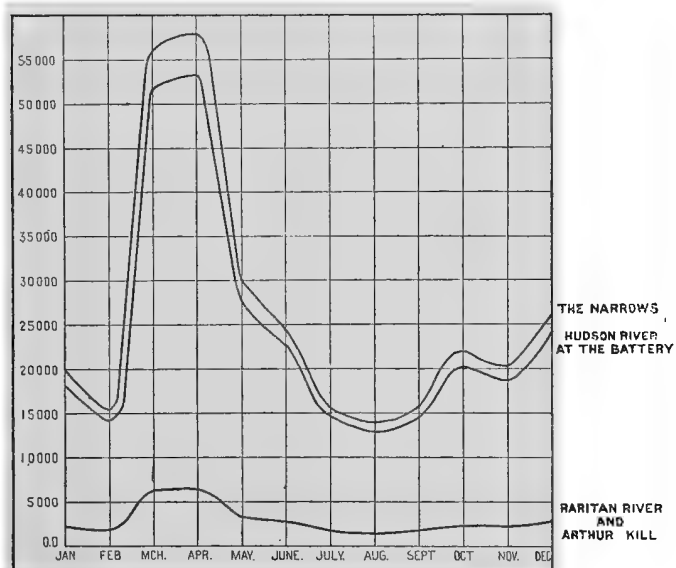
For Ebb	1,639,934,000 cubic feet
For Flood	1,551,658,000 “ “
Excess or Resultant.....	88,276,000 “ “

The Commission has estimated the volumes discharged past sections off Port Richmond and near Bergen Point, using current velocities as given in Tide Tables, and obtained:

For Ebb	1,479,000,000 cubic feet
For Flood	1,391,000,000 “ “
Excess or Resultant.....	88,000,000 “ “



**VOLUMES OF WATER FLOWING IN DIFFERENT CHANNELS
DURING EACH LUNAR HOUR**



**AVERAGE DISCHARGE OF LAND WATER IN
CUBIC FEET PER SECOND**

Harlem River. The Harlem river is a strait joining the so-called East river and the Hudson river.

By ebb current is meant the northerly flow of the river or the volume of water discharged into the Hudson river.

By flood current is meant the southerly flow of the river or the volume of water discharged into the East river.

The Commission has estimated the quantity of water transmitted on both ebb and flood currents, using the current velocities from the float observations made by the Metropolitan Sewerage Commission. Two sections were taken—one opposite 144th street, Manhattan, and one 600 feet north of High Bridge.

The results as computed for these two sections were averaged with the following results:

For Ebb	176,100,000 cubic feet
For Flood	153,500,000 " "
Excess or Resultant.....	22,600,000 " "

TABLE VI

VOLUMES OF FLOW IN MILLIONS OF CUBIC FEET PER LUNAR HOUR IN NEW YORK HARBOR

Lunar Hour	Hudson River		East River		Kill van Kull		The Narrows		Water in Upper Bay	
	Into Upper Bay	Out of Upper Bay	Into Upper Bay	Out of Upper Bay	Into Upper Bay	Out of Upper Bay	Into Upper Bay	Out of Upper Bay	Decreasing	Increasing
I	1,600	....	1,010	....	340	....	....	3,160	290	....
II	1,730	....	730	....	160	....	....	2,490	....	70
III.....	1,430	....	260	....	....	55	....	1,120	....	400
IV.....	710	....	....	270	....	250	430	....	....	600
V.....	....	155	....	730	....	380	1,820	....	....	650
VI.....	....	860	....	1,010	....	400	2,690	....	....	540
VII.....	....	1,360	....	990	....	320	2,840	....	....	290
VIII.....	....	1,460	....	710	....	150	2,230	....	70	....
IX.....	....	1,200	....	260	70	....	1,020	....	400	....
X.....	....	600	290	....	260	....	....	480	600	....
XI.....	200	....	750	....	390	....	....	2,060	650	....
XII.....	1,050	....	1,030	....	420	....	....	3,000	540	....
Ebb flow.....	6,720	....	4,070	....	1,640	....	....	12,310	2,550	2,550
Flood flow.....	....	5,635	....	3,970	....	1,555	11,030	....	....	....

VOLUMES OF TIDAL FLOW INTO AND OUT OF THE UPPER BAY

General Conditions. Taking the Upper bay as a central basin, the entrances and exits are the East river, Hudson river, Kill van Kull, and the Narrows.

Into the Upper bay there is a discharge of water from the Hudson river and a proportion of the discharge of the Hackensack and Passaic rivers as well as the resultant flow from the Sound through the East river. This resultant flow through the East river toward the Upper bay may or may not be great, but under normal conditions there is a small resultant discharge into the bay. In consequence, there is a net flow of water seaward through the Narrows and the effect of this seaward flow is felt possibly some sixty miles off Sandy Hook.*

While the water is flowing into and out of the Upper bay during a full tidal cycle the volume of water in the Upper bay is changing, as is shown by the rise and fall of its water surface. In order to create this rise more water must flow into the Upper bay during approximately six lunar hours than runs out during the same hours. The converse is also true. As the water surface of the Upper bay is nearly twenty-one square miles, and the mean range of tide is 4.4 feet, the tidal prism and also the volume of tidal change between any two periods of time can be estimated.

Method of Estimating. The rates or volumes of flow, in millions of cubic feet per lunar hour, are shown graphically on page 177. To determine the volumes of flow through any one of the entrances to the Upper bay at any given lunar hour, measure the ordinate, or vertical distance from the horizontal base line to the proper curve in accordance with the scale marked on the diagram.

These rates of flow are those under mean conditions and are sufficiently accurate for all practical purposes.

Fig. 3 was constructed by assuming that the rates of flow vary as the ordinates of a curve of sines. Therefore, for each tidal flow a sine curve was drawn to scale, so that its horizontal length would represent the number of lunar hours that the current would flow on either ebb or flood and its area between the curve and the base line would represent the volumes of flow transmitted, as estimated above. Dividing any volume of tidal discharge, as given, by six will give the average flow for one lunar hour. Multiplying this result by $\pi \div 2$, which is the ratio that the maximum ordinate of a sine curve bears to its average ordinate, will give the maximum flow for the current selected. This point was plotted to scale and a sine curve drawn through it. This work was repeated for each division of the harbor.

By scaling the curves given in Fig. 3 at each lunar hour, the volumes of flow for each lunar hour were obtained and tabulated in Table VI.

*U. S. Coast and Geodetic Survey, Vol. III, 1859-60, Appendix 26.

In drawing the curves on Fig. 3, the lunar times were advanced by the number of minutes that the tidal waves required to progress from the Upper bay to the sections selected for estimating the volumes of flow.

DISCHARGE OF WATER THROUGH NEW YORK HARBOR TO THE SEA

There is a resultant flow or discharge of water through the East river and New York bay from Long Island Sound to the ocean. The net discharge through the East river is, however, according to the Coast and Geodetic Survey, small and not in excess of one or two per cent. of the flood flow.

Net Flow into Bay from Sound. According to an estimate made by the Commission, the volume transmitted on the ebb is about 12 per cent. greater than the volume transmitted on the flood, but it must be admitted that there are not sufficient data, properly taken over a sufficiently long period of time, to warrant a positive statement as to what is the net resultant flow under normal conditions.

Based on the behavior of the floats set adrift by the Metropolitan Sewerage Commission, and on the figures given above, the resultant flow from the Sound into the Upper bay does not play as important a part in flushing out New York harbor as the high currents would indicate. In the light of our present knowledge this resultant flow can be conservatively taken at 100,000,000 cubic feet per tidal cycle of 12 lunar hours.

Net Flow Seaward through Narrows. The net or resultant flow through the Narrows to the sea, is the sum of the resultant flow through the East river and the discharge of land waters from the watersheds draining into the Upper bay.

This land-water, it is estimated, amounts to 26,442 cubic feet per second. As there are 44,714 seconds in 12 lunar hours, the discharge of land-water is 1,182.3 million cubic feet. To this should be added the resultant flow from Long Island Sound through the East river, or 100 million cubic feet.

The mean resultant flow through the Narrows is, therefore, 1,282.3 million cubic feet per tidal cycle of 12 lunar hours.

Under ordinary conditions favorable to a large flow through the Narrows, the resultant flow may be 41 per cent. greater than the mean; and under conditions unfavorable to a large flow, the resultant may be 46 per cent. less than the mean.

CONTROLLING FACTORS WHICH AFFECT THE FLOW OF WATER INTO AND OUT OF NEW YORK HARBOR AND EFFECT PRODUCED BY WIND

The controlling factors which affect the flow of the water into and out of the harbor are:

1. *Land Water Discharge.* The variability of the drainage discharge from month to month from the watersheds drained by the various rivers and creeks entering the harbor, as has been mentioned above.

2. *Variation in Heights of Tides.* The variability of the quantity of water entering or leaving the harbor, depending upon the irregular rise and fall of the tide, which is due to the perigean and the apogean ranges, or those in which the influences of the moon and sun act in the same or opposite directions.

3. *Effects of Winds.* The variability of the quantity of water entering or leaving the harbor, due to the effect of the wind, which is very irregular. The ordinary extreme value of the annual fluctuation of the surface of the Upper bay, due to the wind, is about four feet; and on two or three days of each year it is usual for the winds to produce an extreme variation in the water surface of about two feet below or of about two feet above the regular tidal height.

EFFECT OF CHANGES IN DEPTH, WIDTH AND LOCATION OF CHANNELS AND OF CONSTRUCTION OF ISLANDS AND BULKHEADS ON THE DISCHARGE OF WATER THROUGH THE HARBOR

Reclamation. The area of the Upper bay is about 20.7 square miles; of Newark bay about 8.3 square miles; of the Hudson river to Mt. St. Vincent 14.5 square miles, and of the East river 14.8 square miles. The total area is, therefore, 58.3 square miles, and is so large in comparison with any of the reclaimed areas that the flow into and out of the harbor can scarcely be sensibly affected because of the tidal areas lost through the construction of islands and bulkheads.

Pier Extensions. The extension of piers into the rivers, especially the Hudson river, would reduce the amount of tide water passing up and down. However, neither the reclamation of shore areas nor the extension of piers into the Hudson seem, up to the present time, to have sensibly interfered with the tide. For instance, the mean range of tide at Dobbs Ferry, determined from observations made in the years 1856, 1858, 1885, 1886 and 1900, has the values of 3.71, 3.69, 3.58, 3.60 and 3.66 feet respectively, and these figures are apparently sufficiently close to cover the yearly variations.

Dredged Channels. The flow out of and into the harbor is controlled by the Narrows; and the dredging of the channels in the Lower bay will probably produce no sensible alteration in the general circulation of the water in the harbor.

AVERAGE, MAXIMUM AND MINIMUM VELOCITY, IN EACH DIRECTION, OF CURRENTS AT THE
PRINCIPAL POINTS IN NEW YORK HARBOR, AT THE TIME WHEN
EACH CURRENT IS STRONGEST

The velocity of the strongest surface currents for various points in the harbor is given in Table VII. These velocities are surface velocities or the velocity of the water just below the surface.

TABLE VII
VELOCITIES OF CURRENTS IN THE CHANNELS OF NEW YORK HARBOR

	When conditions are					
	Mean		Maximum		Minimum	
	Ebb	Flood	Ebb	Flood	Ebb	Flood
The Narrows.....	2.0	1.6	2.8	2.3	1.1	0.9
Hudson river, 39th street.....	3.0	2.0	4.7	3.0	1.4	1.2
East river, Brooklyn Bridge.....	3.8	3.6	4.6	4.4	2.6	2.5
East river, 11th street.....	3.0	2.9	3.7	3.5	2.1	2.0
East river, 19th street.....	2.6	2.3	3.2	2.8	1.8	1.6
East river, 31st street.....	2.9	2.6	3.5	3.2	2.0	1.8
Kill van Kull, Port Richmond.....	2.2	1.8	2.7	2.2	1.5	1.2
Kill van Kull, Bergen Point.....	2.0	1.8	2.4	2.2	1.4	1.2
Harlem river, 144th street.....	1.0	1.0	1.2	1.2	0.7	0.7
Harlem river, High Bridge.....	1.9	1.8	2.3	2.2	1.3	1.2

The velocities vary even more widely than is shown in the table, and the variations are caused by the variability of the flow from the drainage areas, by the perigean and the apogean range of the tide, by the winds, and by the obstruction of the flow caused by ice.

CHAPTER IV

HARBOR CURRENTS AS SHOWN BY FLOATS

SECTION I

FLOAT EXPERIMENTS

Float experiments were first undertaken in 1907 by the Metropolitan Sewerage Commission to show the direction and velocity of the tidal currents in New York harbor. A second series of experiments was made in 1908 and a third in 1909.

The immediate object of these experiments was to gain information as to the probable drift of sewage and other wastes discharged at different points in the harbor at different stages of tide. It was particularly desired to learn how long it would take such material to pass out to sea.

Some information on this subject was available in publications of the United States Coast and Geodetic Survey, but most of it related to movements in the main channel of the Upper bay and Hudson and East rivers. There is little definite knowledge regarding the currents in the Harlem river, Kill van Kull and other small bodies of water or of currents near shore. The information which was lacking was particularly needed in connection with the questions of sewage disposal which the commission had to study. The conditions at the proposed outlet of the Passaic valley sewer near Robbins Reef were of special interest.

METHODS OF WORK EMPLOYED

From the well-known fact that sewage discharged into salt or brackish water tends to rise and flow off at the surface it was believed that floats of moderate depth would indicate the path likely to be taken by sewage if discharged either at or below the surface. It was evident that floats, however designed, would be affected to some extent by wind. The effect of wind is twofold: *First*, it acts on the area of the float exposed above the water surface, and, *second*, it produces a general movement of the water near the surface to leeward. This movement of the surface water is a conspicuous phenomenon. By reducing the size of that part of the float which projected above the surface of the water and making the flags which it was necessary for the floats to carry as small as practicable the direct effect of the wind was reduced to a point which was considered negligible. As for the drift of the water itself, it was con-

sidered that this movement would convey sewage or other floating material quite as readily as a float, so that the value of the record in indicating what would become of sewage would not be impaired by this effect of the wind.

Points which were considered desirable in selecting the type of float to be used included the following: (*a*) minimum area of float exposed to the wind; (*b*) maximum area of the submerged portion exposed to the currents; (*c*) ability of the float to resist destruction from passing vessels; (*d*) ease with which the float could be handled from the attending boats, especially in stormy weather.

Three types of floats were used at different times in the course of the different series of experiments.

Can Floats. The first consisted of two tin cylinders, an upper and a lower one connected by a wire. The upper cylinder was $5\frac{3}{8}$ inches in diameter by 5 inches in length; it was empty and sealed and carried a small red flag on a staff set in a socket on the upper end of the cylinder. From this upper can, which in action was partly submerged, a larger can $6\frac{1}{4}$ inches in diameter by 14 inches in length was suspended by a copper wire of such length as to permit the larger can to float in the current whose velocity was to be determined. This larger can was weighted with sand until the top of the upper can was nearly level with the surface of the water. This type of float had the advantages of ease of handling, ease of preparation for use, a small area exposed to wind and small cost. On the other hand, where traffic was congested—as in the East river—they were destroyed by the paddles and propellers of steamers. When required for night work they were unable to carry a lantern.

Spar Floats. A second type consisted in a stick of timber 2 inches by 2 inches by 5 feet buoyed by a cork float at the top and carrying four vanes of sheet iron, 12 inches by 24 inches in size. The vanes were nailed to the stick and stayed by a wire which connected their outer edges. This float was readily made and proved to be effective in use. Its chief defect was that the plates were too easily bent when the float was out of water.

A third type was like the second except that it was more substantial. It was made of a 3-inch by 3-inch by 6-foot stick buoyed at one end by being built up to 12 inches by 12 inches for 24 inches from the top and weighted at the other by four vanes of No. 14 gauge iron 18 inches by 21 inches in size, secured by bolts. A $\frac{3}{8}$ -inch rod projected about four feet above the top and was provided with two arms from which were suspended red and white lanterns at night. As this float was heavy and difficult to handle and as the rod was easily bent, a light stiffening frame of $\frac{1}{8}$ -inch by 2-inch iron was attached to the head of the float and supported the rod just below the lantern. To this frame was welded a hook to be grappled in removing the float from the



Small Can Floats Used in Studying Tidal Currents. These floats could easily be followed by observers on a boat in the daytime



Small Can Float in Use. The larger can was filled with water and sand, so that the smaller can was nearly submerged when put in use

water. This design proved satisfactory for the rough seas experienced in December, 1909, in the Lower bay and among the tugs, car floats and ferries of the East river.

Methods of Observing Floats. In studying the currents a float was cast overboard and followed by an observer in a boat. The observer determined the float's position at frequent intervals, generally by means of a sextant, but often, when near shore, by estimating the bearing and distance of the float from a known point, such as a pier or bridge. In some cases, where the distances were not too great, an azimuth compass was used in fixing the bearing.

The positions of the floats were plotted on tracings of United States Coast and Geodetic Survey charts on a scale of $\frac{1}{10,000}$, $\frac{1}{40,000}$ or $\frac{1}{80,000}$, depending on the total distance covered. The velocities of the currents were calculated from the times of observation and the distances scaled from the charts.

Experiments of 1907. Twenty-seven experiments were made in 1907. Of these six were mainly in the Hudson river, two in the lower East river, ten in the Upper bay, two in Kill van Kull and seven in the Lower bay or both Upper and Lower bays. Seven floats were set adrift in the vicinity of Robbins Reef.

The floats were followed with a gasoline boat in the months of February, March, April, June and July. The floats used were of the second type described, *i. e.*, a 2-inch by 2-inch by 5-foot stick with sheet-iron vanes. The floats were usually followed during the continuance of a single ebb or flood current.

Experiments of 1908. Thirty-nine experiments were made in 1908. Of these 13 were mainly in the Harlem river, one in the Hudson river, seven in the East river east of Hell Gate, six in the East river south of Hell Gate, one in Newtown creek, ten in the Upper bay and one in the Lower bay. Nine floats were set adrift from the proposed location of the Passaic valley sewer outlet near Robbins Reef.

These experiments were made in August, September and October from gasoline launches of 30 and 46 feet in length. Double can floats were used throughout. The path taken by a float during the continuance of a single tide was usually studied.

Experiments of 1909. In 1909, 25 experiments were made; they were in two series.

The first series comprised six experiments made in the Arthur Kill and Newark bay in September, October and November. A gasoline launch and double can floats were used as in 1908.

The second series consisted of 19 experiments, carried on night and day between November 8 and December 30. Of these, two were mainly in the Hudson river, ten in

the East river and Long Island Sound, five in the Upper and Lower bays, one in the Kill van Kull and one in the Arthur Kill.

The type of float used was generally a modification of that employed in 1907, the design finally adopted being that described as the third type.

In following the floats a 62-foot steamboat and a 54-foot gasoline oyster boat were first used, with double crews in 12-hour shifts. Owing to the long distances travelled, the hard service, amounting to 14 or 15 hours per day, was found too arduous. A small launch was then engaged for day use and the men were worked in three shifts per day.

A term of bad weather with high winds and fog then set in, making it difficult for the boats to relieve each other. At times the work was so dangerous that it could not be continued successfully by this plan.

It was finally decided to carry on the work from one properly equipped boat. The 80-foot tugboat *Joseph H. Moran* was secured with a double crew and provisioned for a week. This boat was put into commission November 29 and was used throughout the rest of the work with satisfactory results.

RESULTS OF FLOAT EXPERIMENTS

Hudson River. The records of six floats set out in 1907, five set out in 1908 and three set out in 1909, were wholly or in part in the Hudson river.

Those covering an entire run of tide were the following:

A float set adrift July 19, 1907, opposite Fernbrook street, Yonkers, traveled to Thirty-fifth street, Manhattan—a distance of $12\frac{3}{4}$ miles—in 6 hours 28 minutes. The float followed the middle of the river to Spuyten Duyvil and then varied from near the middle, opposite One Hundred and Fifty-fifth street, to one-sixth the distance across opposite Grant's Tomb. There was a light north wind. The average velocity was about two statute miles per hour and the maximum velocity about three miles per hour opposite Fort Washington Point.

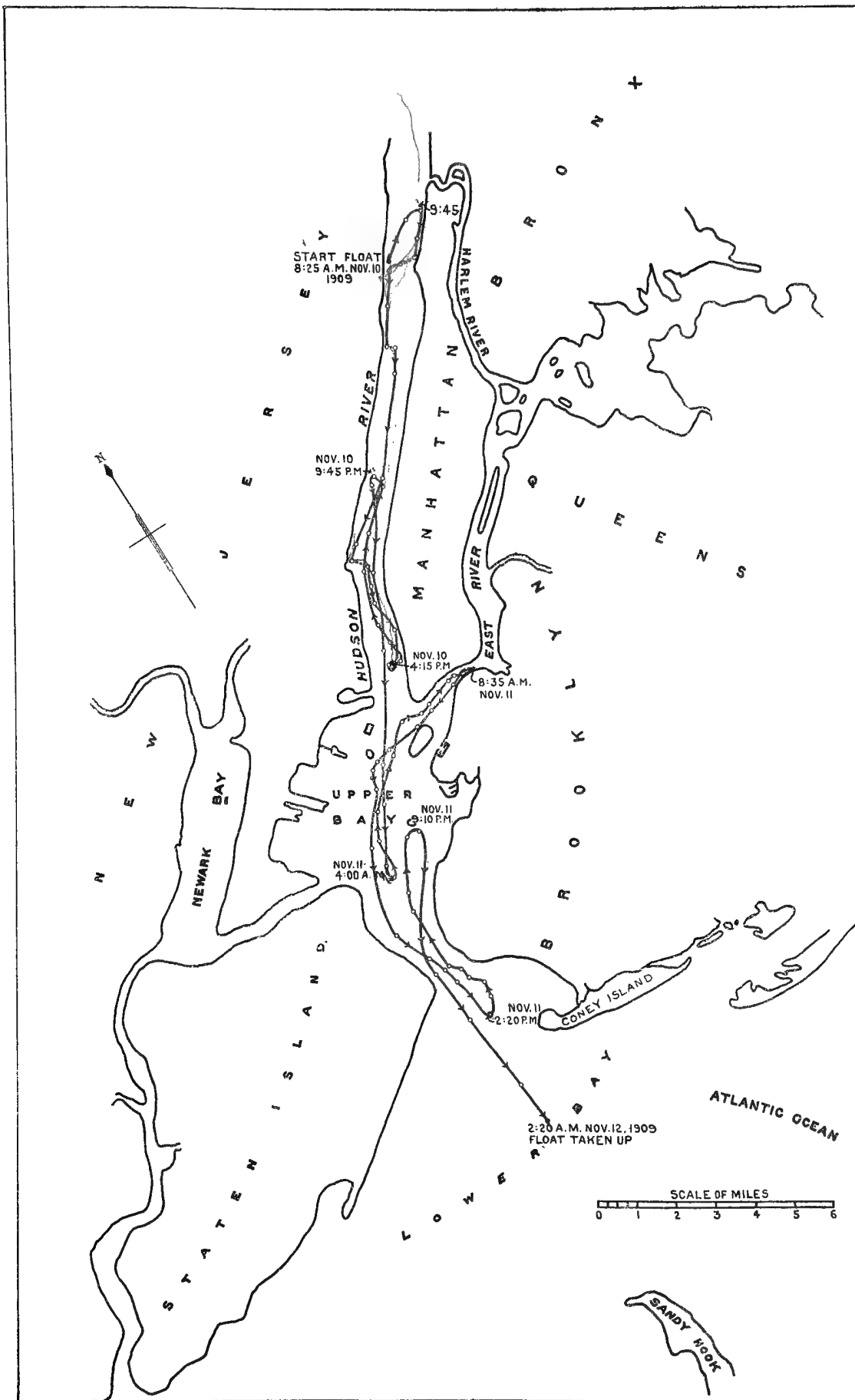
Float No. 34 was set adrift September 9, 1908, in the Harlem river ship canal at Spuyten Duyvil at the end of the flood current. It then went 0.4 mile eastward. At 8.30 A. M. it reversed its direction with the tide. Passing out to the Hudson at 8.46 A. M. it encountered the flood current still running in that stream. This carried it northerly about one and two-third miles and to about one-fourth the width of the stream from the western shore. Here the current remained slack 52 minutes and then turned to ebb at 10.19 A. M. carrying the float down stream. It was opposite West Forty-fifth street, 11 miles, in 5 hours 44 minutes. The mean velocity



Large Float Used in Day and Night Studies of Tidal Currents. This large, strongly constructed float was followed continuously, lighted lanterns showing its location at night



Large Float Used in Current Studies Showing Appearance when Submerged. The lights could be followed without difficulty at night



Path of a Float in the Lower bay and the Upper bay and the Hudson river

was 1.92 miles per hour and the maximum velocity 2.97 miles per hour. The course followed was generally near the middle of the river but it approached to 0.1 mile of the east side at the mouth of the Harlem river and within 0.2 mile of the west side opposite Inwood. The wind was southerly, increasing from light to strong.

Float 46 was set adrift at the proposed outlet of the Bronx valley sewer off Mt. St. Vincent November 8, 1909, at 11.03 P. M. soon after slack water. It passed down stream 10.81 miles to a point opposite West Sixty-seventh street. It reached there at 3.45 A. M. and remained stationary 25 minutes during slack water. The flood current carried the float to One Hundred and Tenth street and the next ebb took it to Communipaw, where it arrived at 1.40 P. M.

Float 47 was set adrift off Mt. St. Vincent November 9, 1909, at 9.52 P. M. at the turn of the tide. It was taken out November 12, at 2.20 A. M., $2\frac{1}{2}$ miles south-south-west of Norton Point near the end of the ebb current. The float had been in the water five ebb tides and four flood tides and the net progression had been $28\frac{1}{4}$ miles. The average progression toward the sea per tidal cycle of 12 lunar hours was five miles. The average progression per tide while in the Harlem river was about five and one-half miles.

It is noteworthy that floats which entered the Hudson from the Harlem river generally hugged the easterly shore in passing down stream.

From the work done in the Hudson river the mean and maximum velocities on ebb currents were found to be about two and three miles per hour respectively and those on the flood current one mile and two miles per hour respectively. These figures vary to a considerable degree depending on the amount of land water flowing down the river.

Harlem River. The Harlem river extends from Hell Gate to Spuyten Duyvil, a distance of seven and five-eighth miles. Thirteen float records were obtained in this stream, all in the series of 1908.

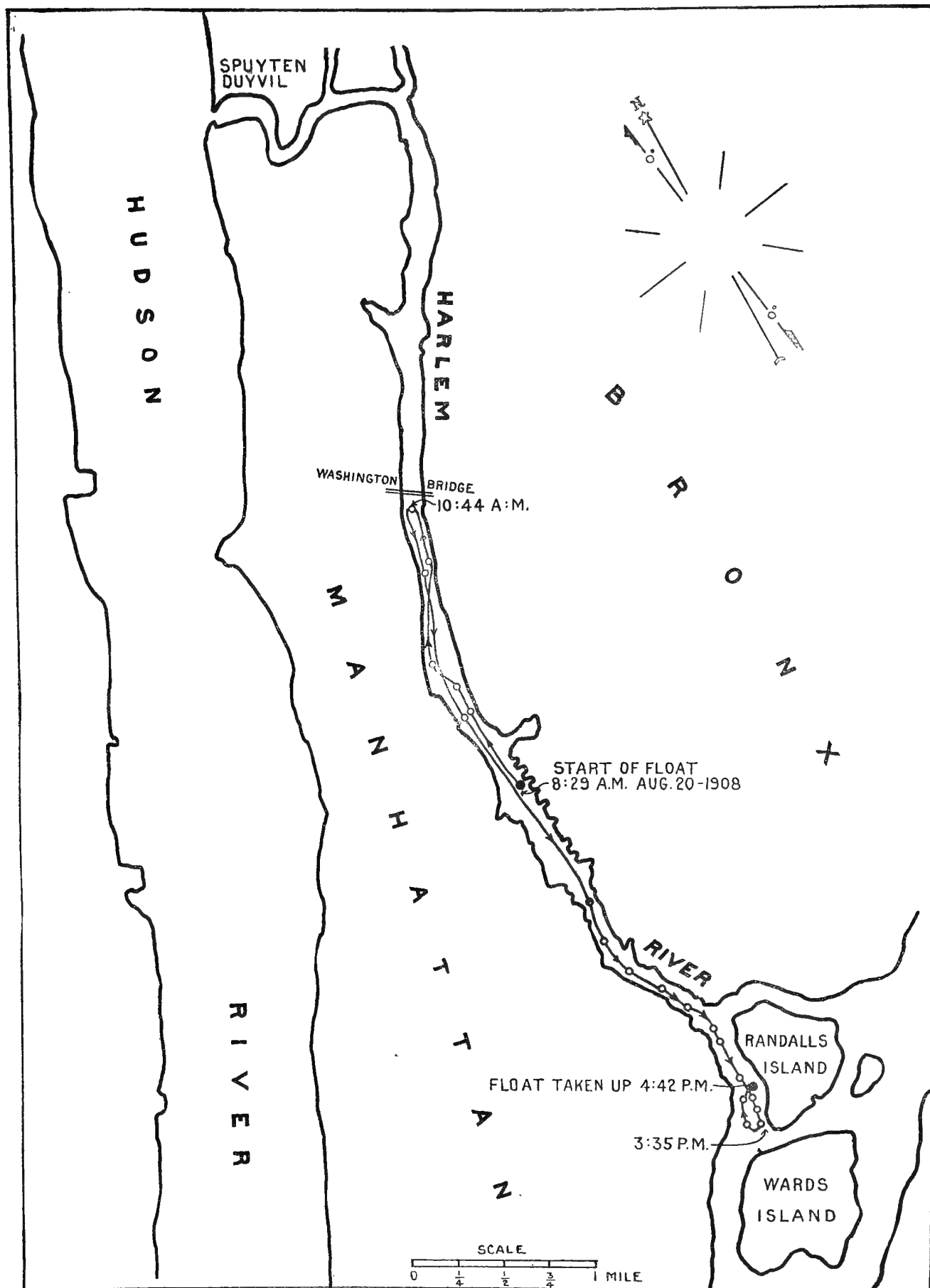
Float No. 5, set out August 7, traversed 6.05 miles in 4 hours 52 minutes. The mean velocity was 1.24 and the maximum 2.35 miles per hour.

Float No. 7,* set out August 19, made 4.70 miles in 6 hours 2 minutes. The mean velocity was 0.78 mile per hour. The maximum velocity was 1.93 miles per hour.

Float No. 8, set out August 20, covered 4.05 miles in 4 hours 51 minutes. The mean velocity was 0.89 mile per hour and the maximum velocity 1.31 miles per hour.

Of the foregoing the paths of floats Nos. 5, 7 and 8 represented entire flood currents.

*This record was interrupted for 20 minutes, during which time the boat drifted with the current.



Path of a Float in the Harlem River

Of the other experiments float No. 6, August 18, showed the existence of a strong current toward the Sound through Bronx Kills and Little Hell Gate.

Of the floats observed on ebb currents Nos. 11, 12 and 13, August 25, 26 and 27, passed into and down the Hudson river. No. 13 covered the entire length north of Bronx Kills, 6.95 miles. Its mean velocity was 1.30 and its maximum 2.36 miles per hour.

Eddies which may favor deposition of sediment occur at certain stages of the tide at each end of the Harlem river and last for a considerable interval, as illustrated by the following examples:

Float No. 2, set out August 15, drifted in an ellipse about 1,100 feet in length west of Randalls Island from 16 minutes to 3 hours 22 minutes after the time of high water at Governors Island, when it was removed from the water.

Float No. 6, set out August 18, drifted to the west shore of Randalls Island 2 hours 57 minutes after the time of low water at Governors Island. This float was reset three times in midstream and each time drifted southeasterly toward the Randalls Island shore, being finally removed 5 hours 2 minutes after low water at Governors Island. A strong current was setting to the east at this time through Little Hell Gate. The wind was westerly but not strong.

Float No. 9 was set adrift August 21 at East One Hundred and Twelfth street, just south of Little Hell Gate 5 hours 6 minutes after high water at Governors Island. It drifted to East One Hundred and Fourth street by 0h. 53 minutes after the time of low water at Governors Island, then northerly to above One Hundred and Seventeenth street in 3 hours, and then wandered between this point and One Hundred and Fifteenth street for two hours, when it was removed. In seven hours the extreme limits of its path did not exceed 0.7 mile.

Float No. 12, set out August 26, passed under the New York Central and Hudson River Railroad bridge at Spuyten Duyvil into the Hudson river 52 minutes before low water at Governors Island, made two circuits within 450 feet to the south of this point and was taken out about 140 feet southwest of the point, where it passed under the bridge 50 minutes later, when its course was northwesterly.

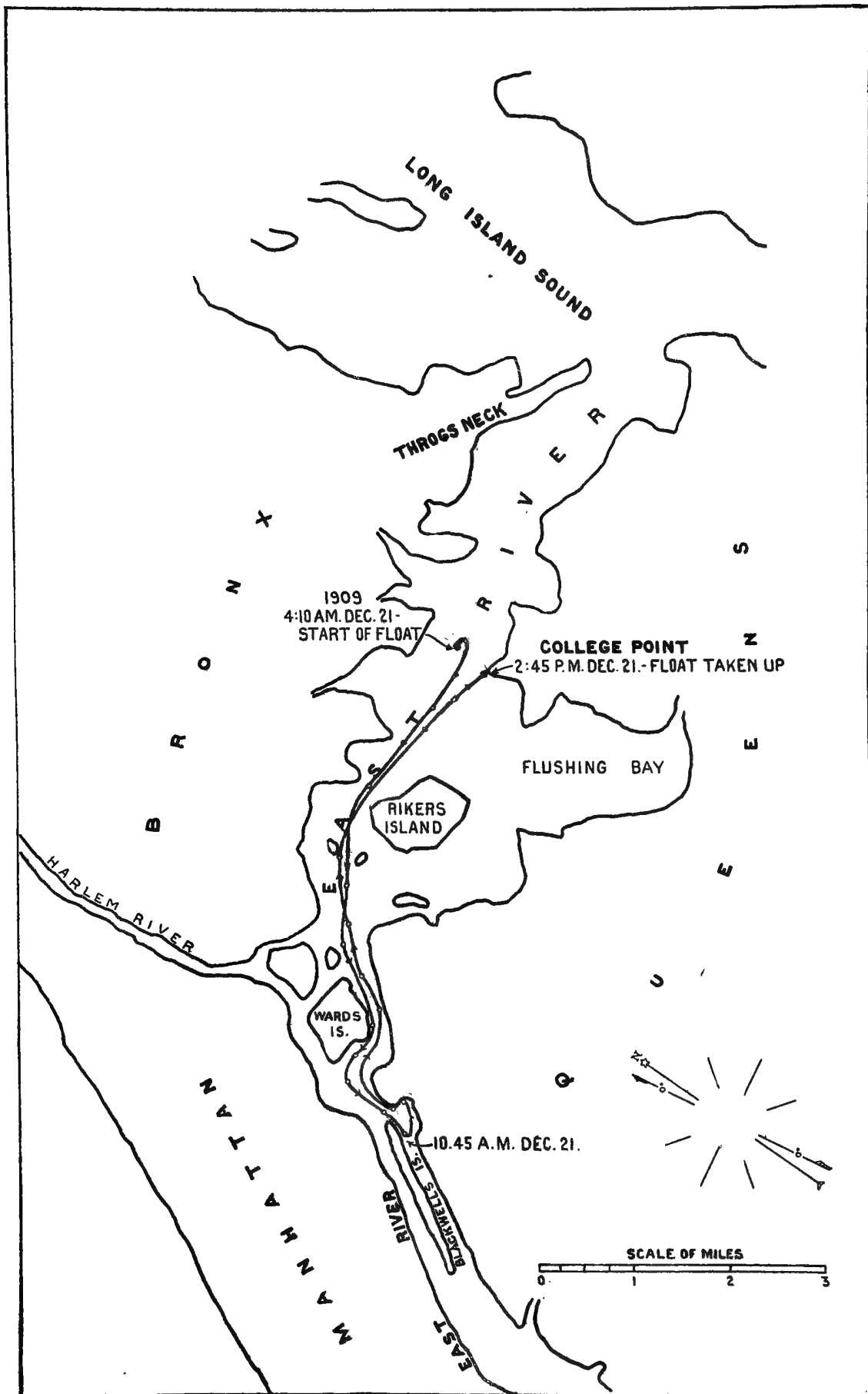
The general conclusions or inferences which it seems fair to draw from the float records in the Harlem may be summed up as follows:

1. The flood current sets in about one and one-half hour after the time of low water of Governors Island.

2. The ebb current sets in at:

One Hundred and Twenty-second street, 1 hour 15 minutes after high water at Governors Island.

One Hundred and Thirty-first street, 1 hour 20 minutes after high water at Governors Island.



Path of a Float in the East River

One Hundred and Thirty-seventh street, 1 hour 23 minutes after high water at Governors Island.

One Hundred and Forty-second street, 1 hour 30 minutes after high water at Governors Island.

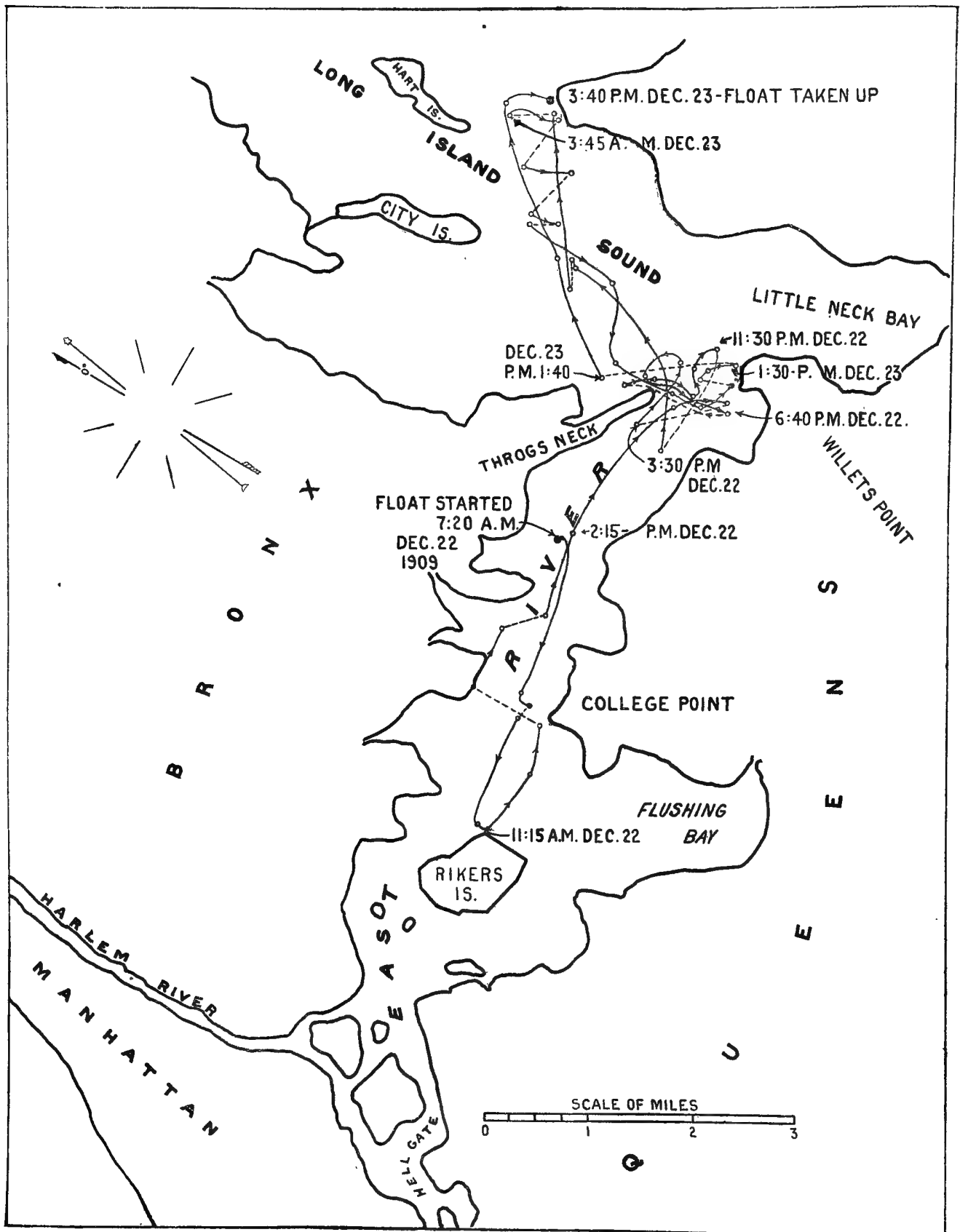
Two Hundred and Nineteenth street, 1 hour 45 minutes after high water at Governors Island.

3. The mean velocity is about 1.4 miles per hour.
4. The maximum velocity is about 2.35 miles per hour on the ebb current, that on the flood being somewhat less.
5. The duration of slack water is brief, usually not more than 15 minutes.
6. There is a preponderance of flow toward the Hudson, the rate of progression being about two miles per tide.
7. The flood tides in the Harlem and lower East rivers meet and the ebb currents part in the vicinity of Randalls and Wards Islands, causing variable currents of small velocity at these times.

Upper East River. As the characteristics of the upper East river, or that part lying east of Hell Gate, are quite different from those of the lower portion, the float records made in these two parts of the river will be considered separately.

Eight floats were observed in the upper East river in 1908 and seven in 1909. The length of this part of the stream, extending from Hallets Point to Throgs Neck, is eight and three-fourth miles. The presence of islands near the western end and the influence of currents to and from the Harlem river render the hydraulic phenomena in that vicinity complicated, while the tortuous paths of floats indicate the absence of any one main channel which conveys at all times the greater part of the flow. An inspection of the Coast Survey charts show no well defined channel, but a waterway varying from about 30 to 100 feet in depth, extending nearly from shore to shore between Throgs Neck and College Point. Here shoals to the east of Rikers Island split the westward current, which becomes further divided in its approach to the Manhattan shore, and the contracted and shallow channels through Hell Gate, Little Hell Gate and Bronx Kills cause an increase in the velocity of the tidal flow. A tendency to drift about some time near Throgs Neck is shown in the following records:

Float 62 was set out at 1.25 P. M December 20, 1909, between Whitestone Point and Willets Point and was taken up 13 hours 45 minutes later off Throgs Neck. In the meantime it had grounded on the south shore five times, due, probably, to a strong northwest wind. The total record covered but about four miles along the channel in this time.



Path of a Float in the East River

Float 64 was set out off Whitestone Point at 7.20 A. M. December 22, 1909. By 11.15 A. M. it reversed its direction when just east of Rikers Island. From 2.15 P. M. to 11.30 P. M. it wandered about within three-fourth mile of Throgs Neck. By 2.45 A. M. December 23 it had progressed eastward to Hewlett Point, by 10.20 A. M. it had returned to a point off Willets Point and at 3.40 P. M. it went aground and was taken up off Hewlett Point.

Floats set adrift near Throgs Neck may pass out through Hell Gate or they may travel in an easterly direction through the Sound. Float No. 60 illustrates the latter case.

Float No. 60 was set out December 14, 1909, just west of Throgs Neck at 2.30 P. M. It started to the west, swung around by Little Neck bay and then traveled eastward. Between 11.25 P. M. and 4.40 the next morning it remained within a mile of Barker Point. It then continued easterly until 9.15 A. M. Here, a mile east of Sands Point, it made a double spiral within a diameter of three-eighth mile during the time of the westerly running tide, and then at 2.25 P. M. proceeded on the easterly tide some three and one-half miles, when it was taken up one and one-fourth mile west of Matinicock Point at 6.45 P. M. December 15.

Maximum velocities were observed in the upper East river of 5.0 miles per hour in the narrow channel east of Wards Island on the ebb, and 4.0 miles per hour just east of Little Hell Gate, and 3.6 miles per hour north of Rikers Island on the flood. To the east of this point from 1.5 to 2.0 miles per hour would probably be more nearly correct.

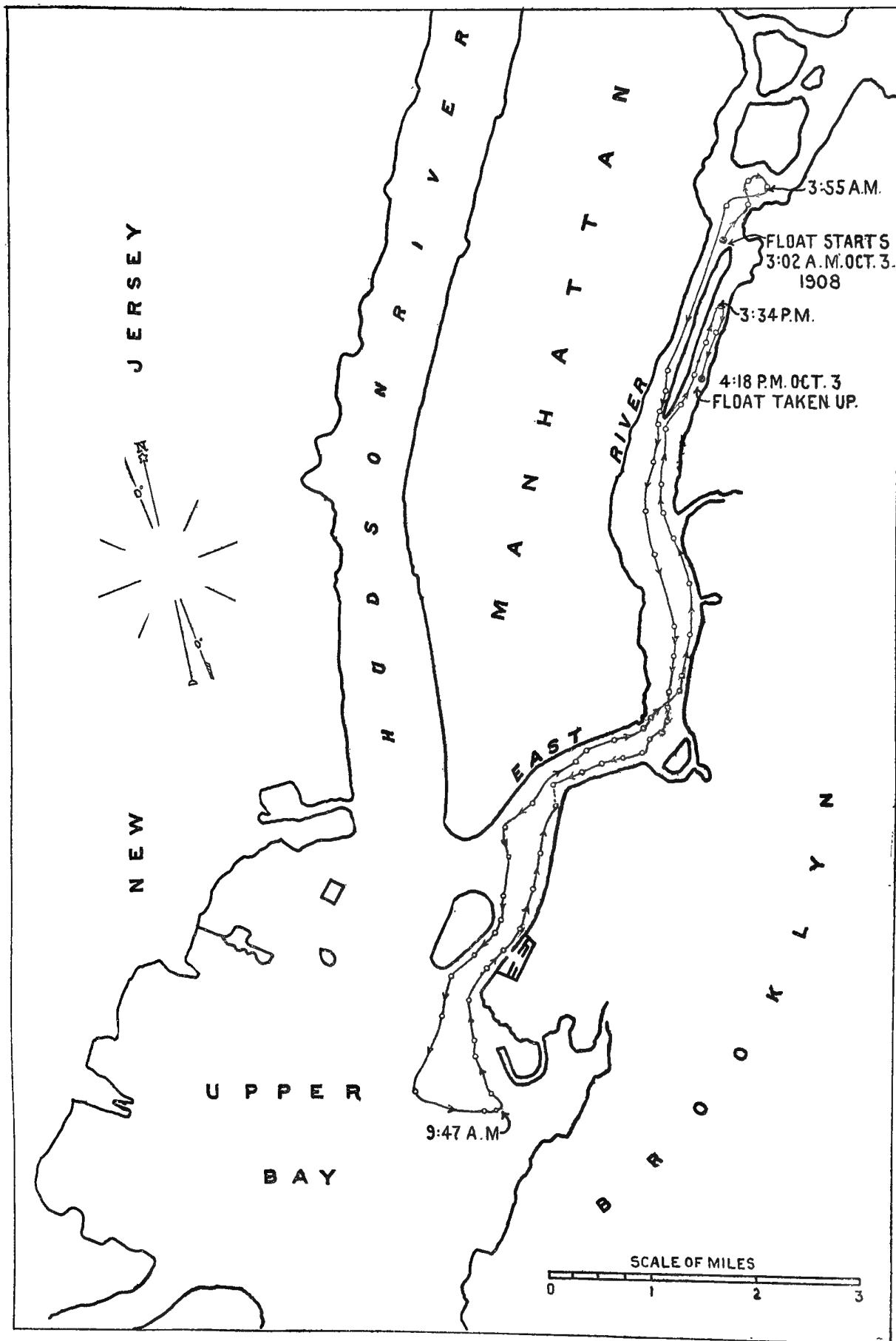
A net progression of the current from the Sound toward Hell Gate appeared probable from the experiments but the results were quite variable and the record of float No. 65, covering three days, indicates that at times this progression is insignificant or altogether absent.

From the courses taken by the majority of the floats in that vicinity the main current to and from the lower East river appears to run through Hell Gate, between North and South Brother Islands and north of Rikers Island.

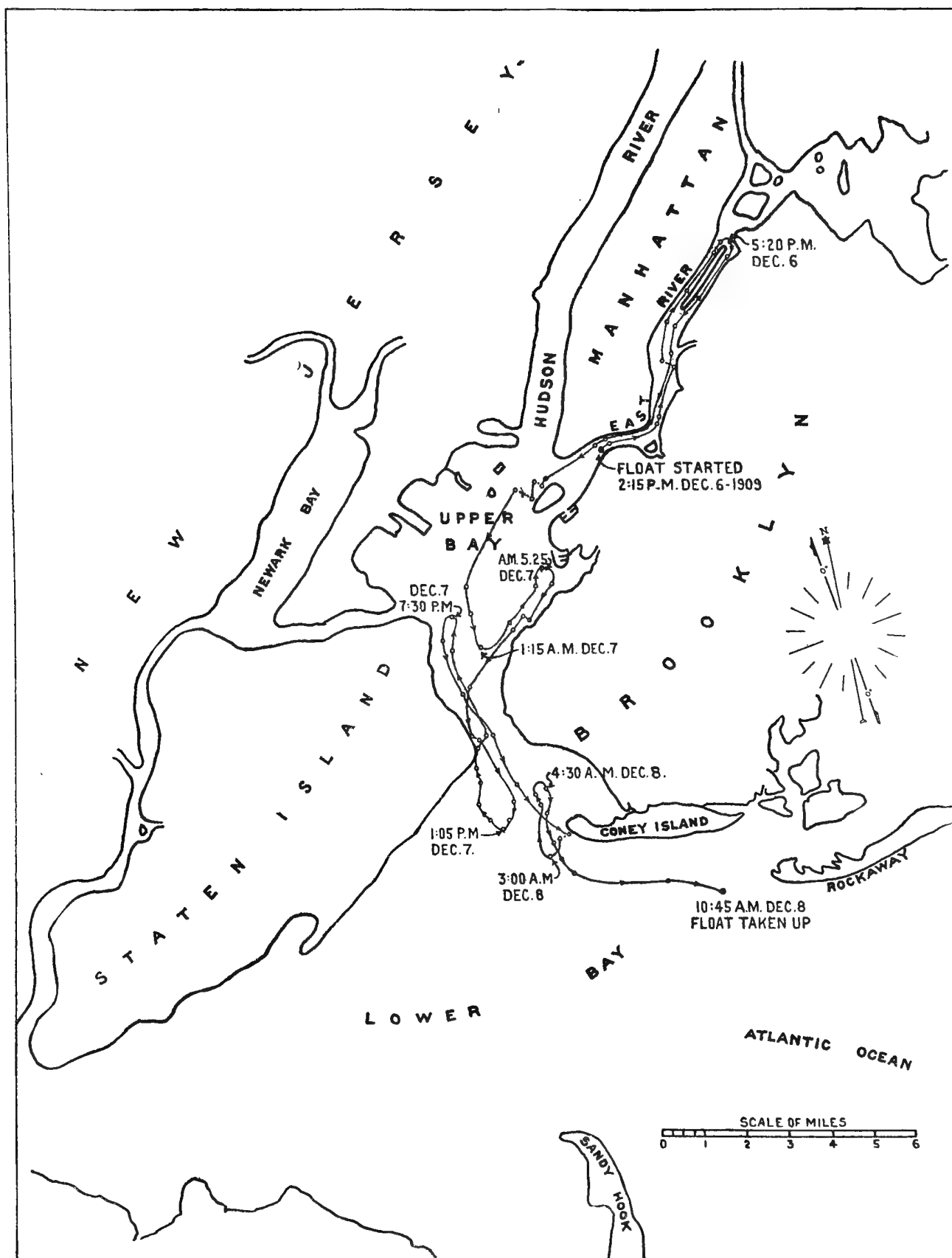
Lower East River. The length of this part of the river is about seven and three-quarter miles. Two floats were observed in the lower East river in 1907, eight in 1908* and nine in 1909.

Owing to the swift currents which prevail, the number of records embracing a complete tide within the limits of this part of the river are few.

*Including one in Newtown creek.



Path of a Float in the Upper Bay and in the East River



Path of a Float in the Lower Bay, Upper Bay and the East River

A float set out March 7, 1907, opposite Pier 8 on the flood current traveled eight miles in 4 hours 47 minutes.

A float cast overboard March 29, 1907, east of Wards Island on the ebb reached the mouth of the river, 8.8 miles distant, in 2 hours 50 minutes.

Float No. 10, set out August 24, 1908, traveled the length of the lower East river on the ebb in 2 hours 20 minutes.

Float No. 23, set out September 8, 1908, traversed on the ebb from the north end of Blackwells Island to the Battery, 7.4 miles, in 1 hour 55 minutes.

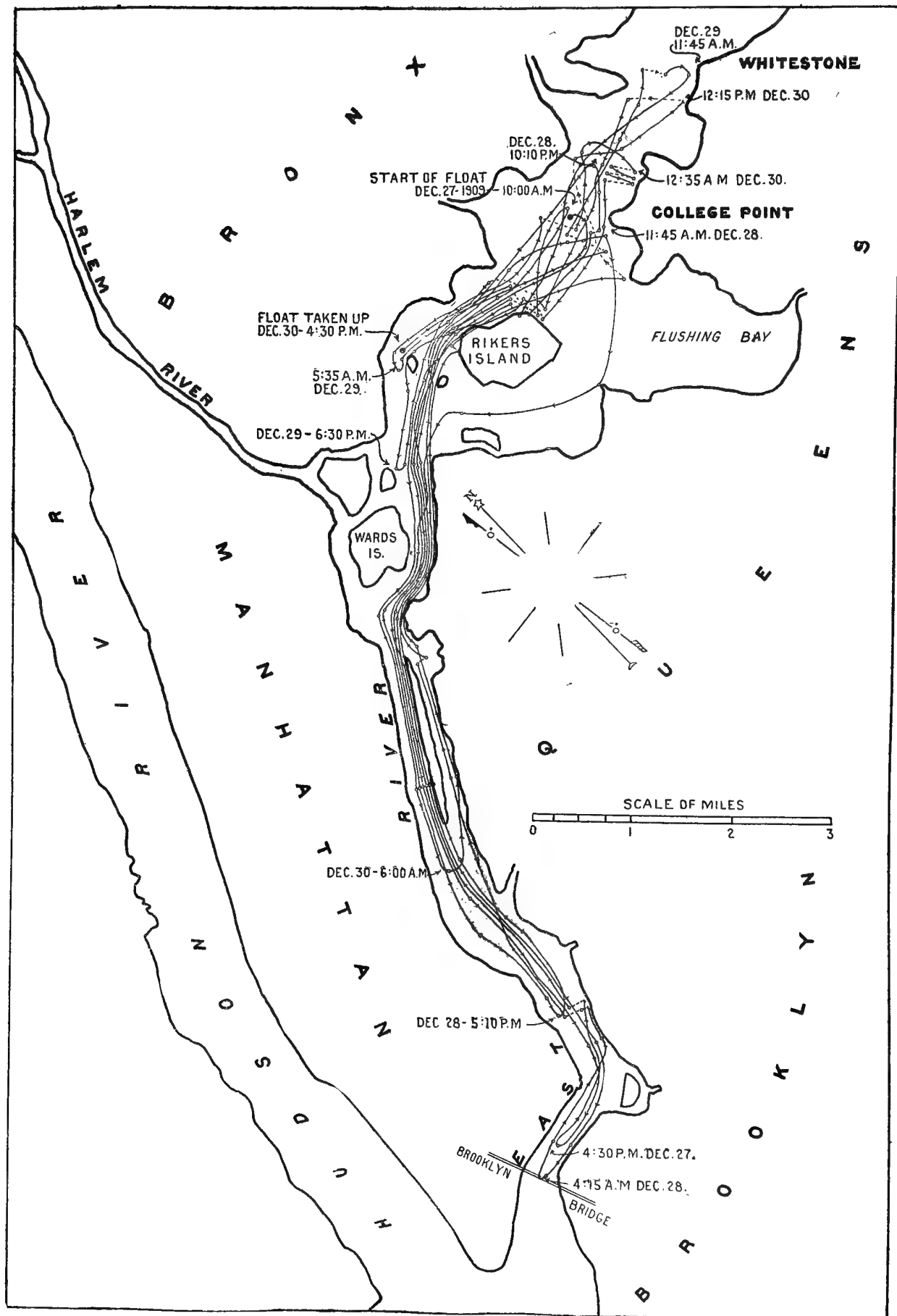
Float No. 36, set out September 30, 1908, covered on the flood from the Battery to Hell Gate, 7.7 miles, in 3 hours 10 minutes.

Float No. 38, set out October 3, 1908, traveled on the flood from the Battery to Hell Gate, 7.7 miles, in 3 hours 8 minutes.

Float No. 57, set out December 6, 1909, traversed on the ebb from north of Blackwells Island, 7.5 miles, in 4 hours 10 minutes.

The records of two floats, chiefly in the East river, are of particular interest. Float No. 36 was set out near the mouth of the East river at 7.42 A. M. September 30, 1908. Following the eastern shore as far as Newtown creek, it passed up the west channel by Blackwells Island, through Hell Gate to North Brother Island. Here the tide turned at 12.34 P. M. and the float returned by about the same course on the ebb current to near the Queensboro Bridge, where it was taken out. The total distance traveled on the flood was 9.69 miles in 4 hours 52 minutes. The mean velocity was 2.09 and the maximum 4.30 miles per hour. On the ebb current a velocity of 6 miles per hour was reached west of Blackwells Island.

Float No. 38 was set adrift October 3, 1908, at 3.02 A. M. west of the north end of Blackwells Island. By 3.55 A. M. it had drifted three-fourths of a mile into Hell Gate, when the current reversed carrying it to Mill Rocks by 4.07 A. M. The float proceeded southward with velocities increasing to four and a half miles per hour west of Blackwells Island. From Wallabout bay it kept on the eastern side of the river to the Manhattan Bridge, at one time covering 1,000 feet in two minutes (5.7 miles per hour) and at another 3,100 feet in eight minutes. From this point the path swerved to the middle of the stream and at 7.12 A. M. was 1,000 feet northeast of Governors Island, having traversed the last 2.62 miles in 40 minutes (3.93 miles per hour). Passing down the west side of the Buttermilk channel the float reached a point 1.2 miles south of Governors Island and about a mile west of the pierhead line at 8.44 A. M. Here, due to a strong west wind and slack tide the float drifted three-fourths of a mile easterly at a rate of about two miles per hour and at 9.37 A. M. turned northerly, passing through the Buttermilk channel and reaching Brooklyn Bridge at 12.47 P. M.,



Path of a Float in the East River

having run ashore five times after leaving the Atlantic basin. At Brooklyn Bridge it was reset 700 feet from the east pier, traveled northerly 1.45 mile in 20 minutes (4.35 miles per hour). The maximum velocity attained was 6.8 miles per hour for a distance of one-third mile when opposite Wallabout bay. Passing to the east of Blackwells Island the float reversed direction sharply with the turn of the tide at 3.34 P. M. 1.35 mile below its position at the beginning of the previous ebb. It was followed till 4.18 P. M. A distance of 10.39 miles were traversed on one ebb in 5 hours 42 minutes at a mean velocity of 1.82 mile per hour, and 9.11 miles on the flood in 5 hours 54 minutes at a mean velocity of 1.54 mile per hour.

Float No. 65 was set out in midstream off College Point in the upper East river December 27, 1909, at 10.00 A. M. Its record follows:

- 11.23 miles on the ebb current to near the Manhattan Bridge;
- 11.34 miles on the flood current to near College Point;
- 12.17 miles on the ebb current to near the Brooklyn Bridge;
- 11.59 miles on the flood current to near College Point;
- 10.49 miles on the ebb current to near East Third street, Manhattan;
- 10.22 miles on the flood current to 1,500 feet off Classon Point;
- 3.69 miles on the ebb current to near the south end of North Brother Island;
- 4.86 miles on the flood current to near Whitestone Point;
- 5.54 miles on the ebb current to near the Sunken Meadow;
- 4.37 miles on the flood current to near Tallman Island;
- 8.93 miles on the ebb current to near East Forty-second street, Manhattan;
- 9.48 miles on the flood current to near Old Ferry Point;
- 3.88 miles on the ebb current to near the northeast of North Brother Island.

It was taken up at North Brother Island, having traveled 107.79 miles in 3 days 6½ hours at an average rate of 1.4 mile per hour. The greatest mean velocity for any one tide was 2.24 miles per hour between College Point and Brooklyn Bridge, and the maximum velocity observed at any one time was 5.37 miles per hour, between the Williamsburg Bridge and Second street, Brooklyn, December 28.

From the observations made in the lower East river the following inferences and conclusions seem justified:

1. The mean velocity of the flood current was two miles per hour and of the ebb current two and three-quarter miles per hour, but the velocity varied in different parts of the channel.
2. The maximum flood velocity was 6.8 miles per hour and the maximum ebb current 8.6 miles per hour for short periods only.
3. The periods of slack water are brief.

4. The main ebb current passes west of Blackwells Island. The main flood current passes sometimes to the west and sometimes to the east of the Island.*

5. There seems to be a tendency for floating matter to drift toward the Brooklyn shore on the flood current. In spite of a "moderate" to "strong" northeast wind, Float No. 36 drifted into three slips between Wallabout bay and Newtown creek and had to be reset.

Upper Bay. In 1907 there were 19 float experiments made in whole or in part in the Upper bay; in 1908 there were 14 and in 1909 six.

Of these 39 experiments 15 were with floats set adrift near the proposed Passaic valley sewer outlet east of Robbins Reef. This point is 3.8 miles from the Battery, one mile from St. George ferry slip and 1.5 miles from Constable Hook.

The extreme points reached in a single tide were:

In the Kill van Kull, Shooters Island, 5.27 miles in 4 hours 38 minutes.

In the Hudson river, Sixtieth street, Manhattan, 9.14 miles in 6 hours 18 minutes.

In the Upper bay (east side), Red Hook, 2.78 miles in 3 hours 23 minutes.

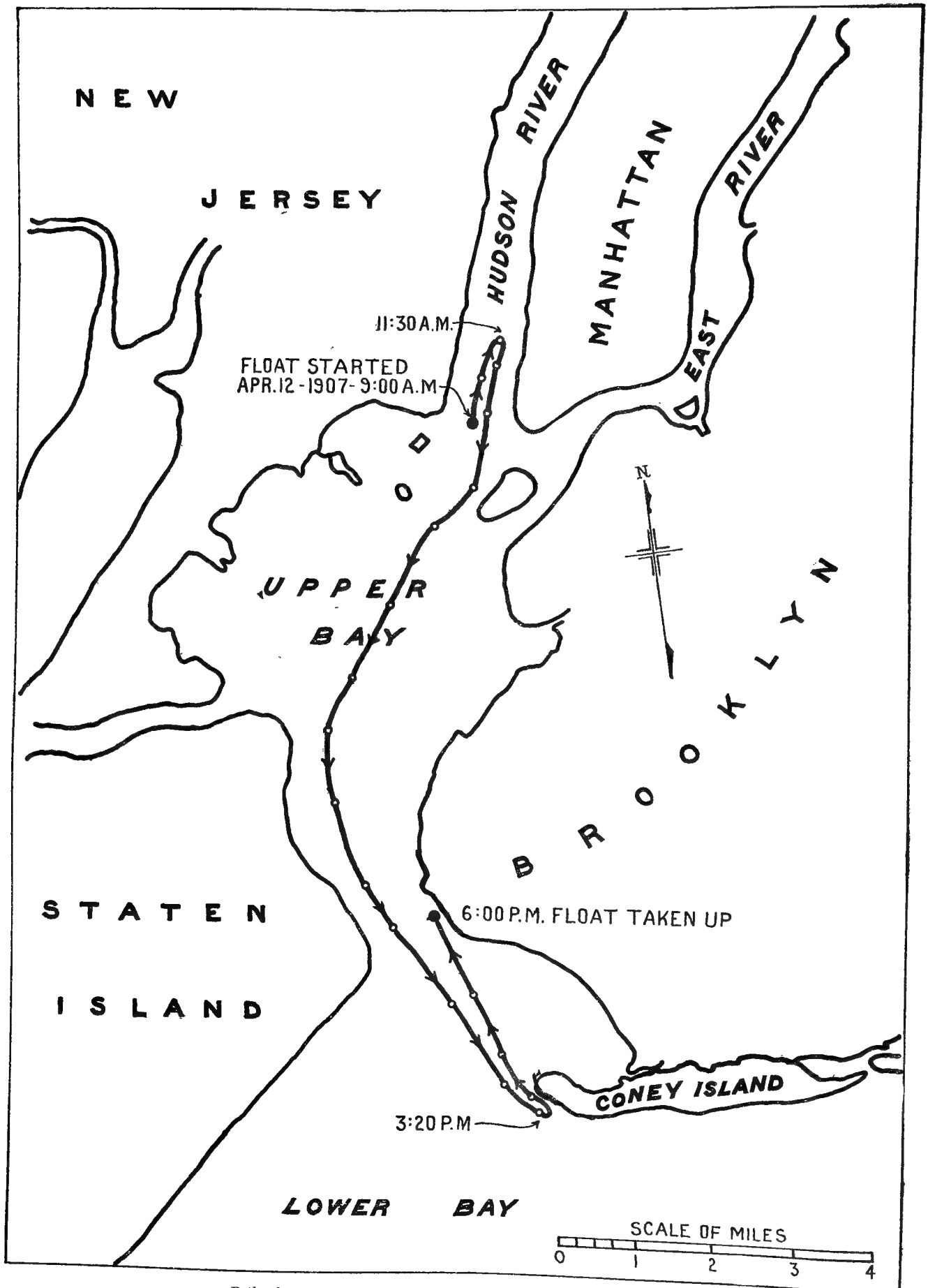
In the Lower bay, $2\frac{3}{8}$ miles southeast of West Bank, 11.50 miles in 6 hours 0 minutes; and 2 miles southwest of West Bank, 11.25 miles in 6 hours 30 minutes.

An examination of the records of the above 15 floats indicates that many passing out with the ebb current hug the shore of Staten Island. The float of February 26, 1907, stranded at Quarantine, that of July 8, 1907, at Clifton, and again at Fort Wadsworth. Nos. 29 and 30 stranded at Stapleton and No. 31 went ashore near South Beach. Of those passing upstream on the flood, that of July 16, 1907, stranded on Liberty Island, No. 28 south of Shooters Island, and No. 35 near Sixty-seventh street, Brooklyn.

*This is confirmed by experiments made with 12 foot and 18 foot rod floats by the United States Coast and Geodetic Survey in 1874.

In the west channel there were twelve experiments on the flood and eight on the ebb current. In the east channel there were seven on the flood and eighteen on the ebb, with the following results:

	West Channel		East Channel	
	Flood	Ebb	Flood	Ebb
Mean velocity in feet per second.....	4.89	6.26	4.42	3.40
Maximum velocity (mean of observations for one hour)	5.77	6.63	5.44	4.04
<i>Excess of mean velocity</i>				
of ebb in west channel.....	....	28 per cent.	.....	....
of flood in east channel.....	....	.....	23 per cent.	....



Path of a Float in the Lower Bay, Upper Bay and Hudson River

Most of the floats set out in the Upper bay and followed for over four hours passed into one of the adjoining rivers or the Lower bay. The records of most value follow:

A float of February 25, 1907, was set out in the mouth of the Hudson at 10.15 A. M. on the ebb. It reversed its direction when near Norton Point, having traveled nine and a half miles in 5 hours 30 minutes, with a mean velocity of 1.75 mile per hour.

Another float was set out in the mouth of the Hudson, March 25, 1907, on the ebb at 9.30 A. M. After traveling eight and one-fourth miles in 4 hours 50 minutes, it reversed its direction off Gravesend bay. The mean velocity was 1.75 miles per hour.

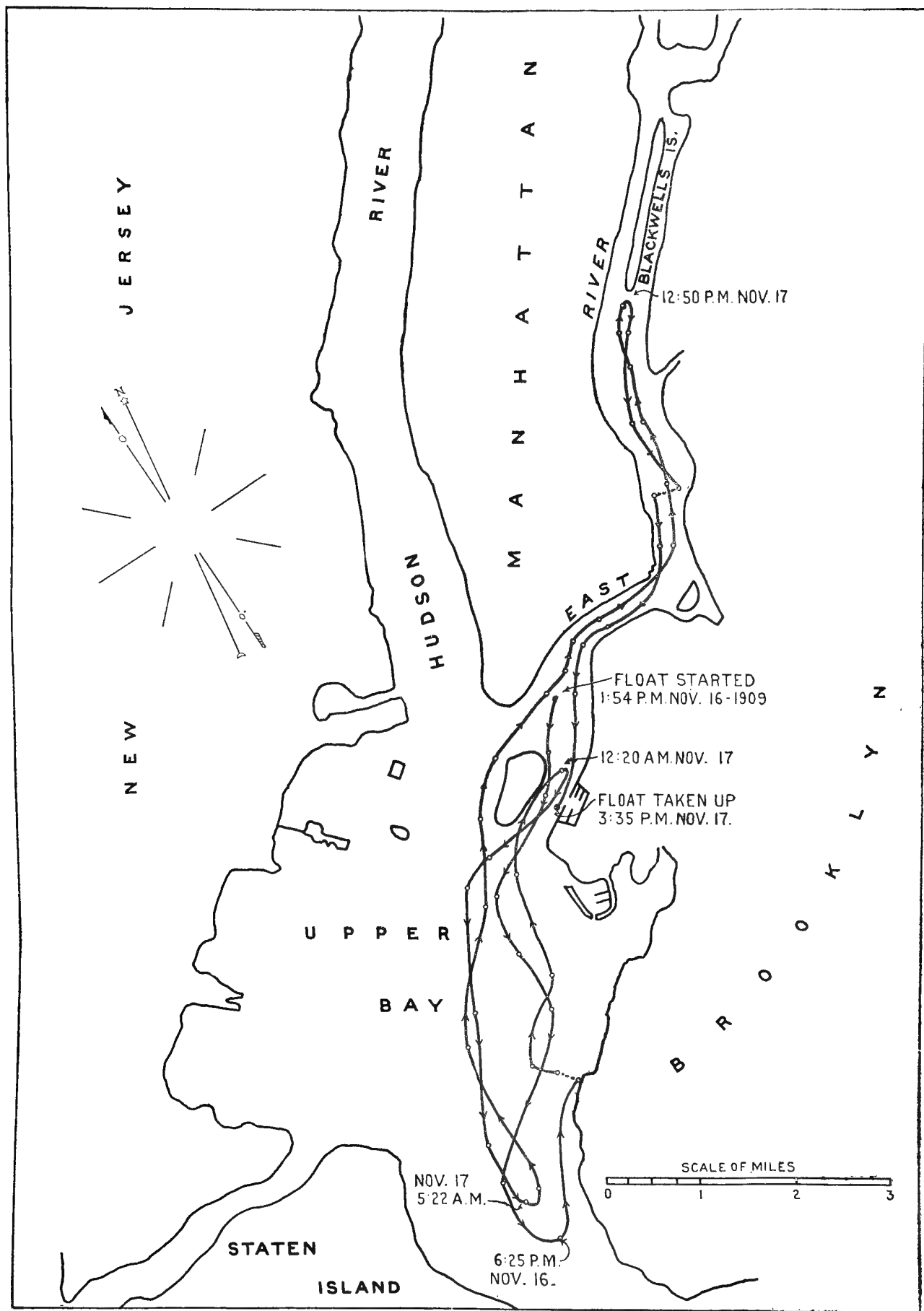
March 27, 1907, a float was set adrift east of Governors Island at 9.30 A. M. on the ebb. It passed down Buttermilk channel and through the Narrows to a point off Norton Point, where it was taken up as the tide was turning at 3 P. M. It had traveled nine miles in 5 hours 30 minutes at an average rate of 1.6 mile per hour.

April 12, 1907, a float was set out at the mouth of the Hudson near the end of the flood at 9 A. M. At 10.40 A. M. it reversed direction about one and one-eighth mile upstream and then passed down through the Lower bay, reversing its direction just south of Norton Point at 3.40 P. M., having traveled 12 miles in five hours. The average velocity was 2.4 miles per hour.

Float No. 39 was set adrift off the outlet of the Sixty-fourth street, Brooklyn, sewer October 5, 1908, at 11.35 A. M. It drifted on the flood current near the pier-heads, through Buttermilk channel and up the East river to Man-of-War Reef, between Newtown creek and Blackwells Island, where it reversed its direction at 5.45 P. M., having traveled 8.97 miles in 6 hours 10 minutes with an average velocity of 1.43 mile per hour.

Float No. 49 was set adrift November 16, 1909, in the mouth of the East river at 1.54 P. M. Passing through Buttermilk channel it reached a point about a mile from the Narrows at 6.25 P. M. Returning on the flood it reversed its direction again east of Governors Island at 12.20 A. M. November 17. By the next turn of tide, which occurred at 5.22 A. M., it had only reached a point off Bay Ridge one and one-half mile from the Narrows. From here the flood current took it to the south end of Blackwells Island, a distance of 9.78 miles, in 7 hours 28 minutes. It was taken up off the Atlantic basin at 3.35 P. M.

Float No. 57 was set out at the Brooklyn Bridge December 6, 1909, at 2.15 P. M. It went up the west channel and rounded Blackwells Island at 5.20 P. M. The ebb current then carried it to Bay Ridge, the flood took it to Gowanus bay, the next ebb took it to Hoffman Island, the flood carried it to a point off St. George, and on the



Path of a Float in the Upper Bay and East River

next ebb it reached Norton Point. It remained within a mile of this point during the next flood current and then passed out to sea by Rockaway Point.

FLOAT RECORDS IN THE UPPER BAY OF AT LEAST FIVE HOURS' DURATION

Records Made on Flood Currents. The float of March 5, 1907, drifted from near Robbins Reef to West Fifty-fourth street, Manhattan, or 8 miles, in 6 hours 45 minutes.

The float of March 22, 1907, drifted from near Fort Lafayette to Sixty-sixth street, Brooklyn, or $2\frac{3}{4}$ miles, in 5 hours 0 minutes.

Float No. 34 drifted from near Robbins Reef to West Sixtieth street, Manhattan, or 9.14 miles, in 6 hours 18 minutes.

Float No. 37 drifted from near Robbins Reef to Bank street, Manhattan, or 6.85 miles, in 6 hours 20 minutes.

Float No. 39 drifted from near Sixty-fourth street, Brooklyn, to East Fortieth street, Manhattan, or 8.97 miles, in 6 hours 20 minutes.

Records Made on Ebb Currents. The float of February 23, 1907, drifted from Gowanus bay to one-half mile south of Romer Shoal, or 12 miles, in 7 hours 0 minutes.

The float of February 25, 1907, drifted from the mouth of the Hudson to a point off Norton Point, or 9.5 miles, in 5 hours 30 minutes.

The float of February 26, 1907, drifted from one mile northeast of Robbins Reef to two and three-eighths miles southeast of West Bank, or 11.5 miles, in 6 hours 0 minutes.

The float of March 27, 1907, drifted from Irving street, Brooklyn, to off Norton Point, or 9 miles, in 5 hours 30 minutes.

The float of April 12, 1907, drifted from one and one-fourth mile above the mouth of the Hudson to a point off Norton Point, or 12 miles, in 5 hours 0 minutes.

The float of July 9, 1907, drifted from one and one-half mile east of Robbins Reef to two miles southwest of West Bank, or 11.25 miles, in 6 hours 30 minutes.

Float No. 32 drifted from one mile northeast of Robbins Reef to a point off Hoffman Island, or 7.53 miles, in 5 hours 12 minutes.

A consideration of the results obtained in the Upper bay leads to following conclusions:

1. Floating matter starting in the channel near Robbins Reef may within one tidal period reach the shores of the Hudson as far as Sixtieth street, Manhattan, or of Staten Island at any point in the Kill van Kull, Upper bay or Lower bay as far as South Beach. It may strand on the Brooklyn shore at any point south of Red Hook with a westerly wind, but a strong ebb current may carry it out as far as Romer Shoal.

2. There is a probability that much will reach the shores of the Kill van Kull or Upper bay before passing out through the Narrows.

3. Floating matter starting in the channel at the Narrows on the beginning of the current might be carried up the Hudson as far as Warren street, and on the return ebb current pass out nearly to Coney Island Light. But these distances depend largely on the land water flowing down the Hudson, the wind and the tide due to the phase of the moon.

4. Ordinary velocities encountered in the Upper bay on the flood are: Mean, 1.2 mile per hour. Maximum, 1.8 mile per hour.

5. Ordinary velocities encountered in the Upper bay on the ebb are: Mean, 1.6 mile per hour. Maximum, 2.5 to 3.1 miles per hour.

Newark Bay, Kill van Kull and Arthur Kill. In 1907 two float records were obtained in the Kill van Kull; in 1908 one float record was obtained in the Kill van Kull and in 1909 one record was obtained in the Kill van Kull and Newark bay and seven in the Arthur Kill and Newark bay.

April 3, 1907, a float set out in Newark bay three-fourth mile north of Bergen Point traveled through the Narrows to a point off Norton Point in 5 hours 25 minutes. It passed through the Kill van Kull in 1 hour 20 minutes.

April 8, 1907, a float traveled from the east end of the Kill van Kull 5.1 miles westerly on the flood current in five hours at a mean velocity of one mile per hour.

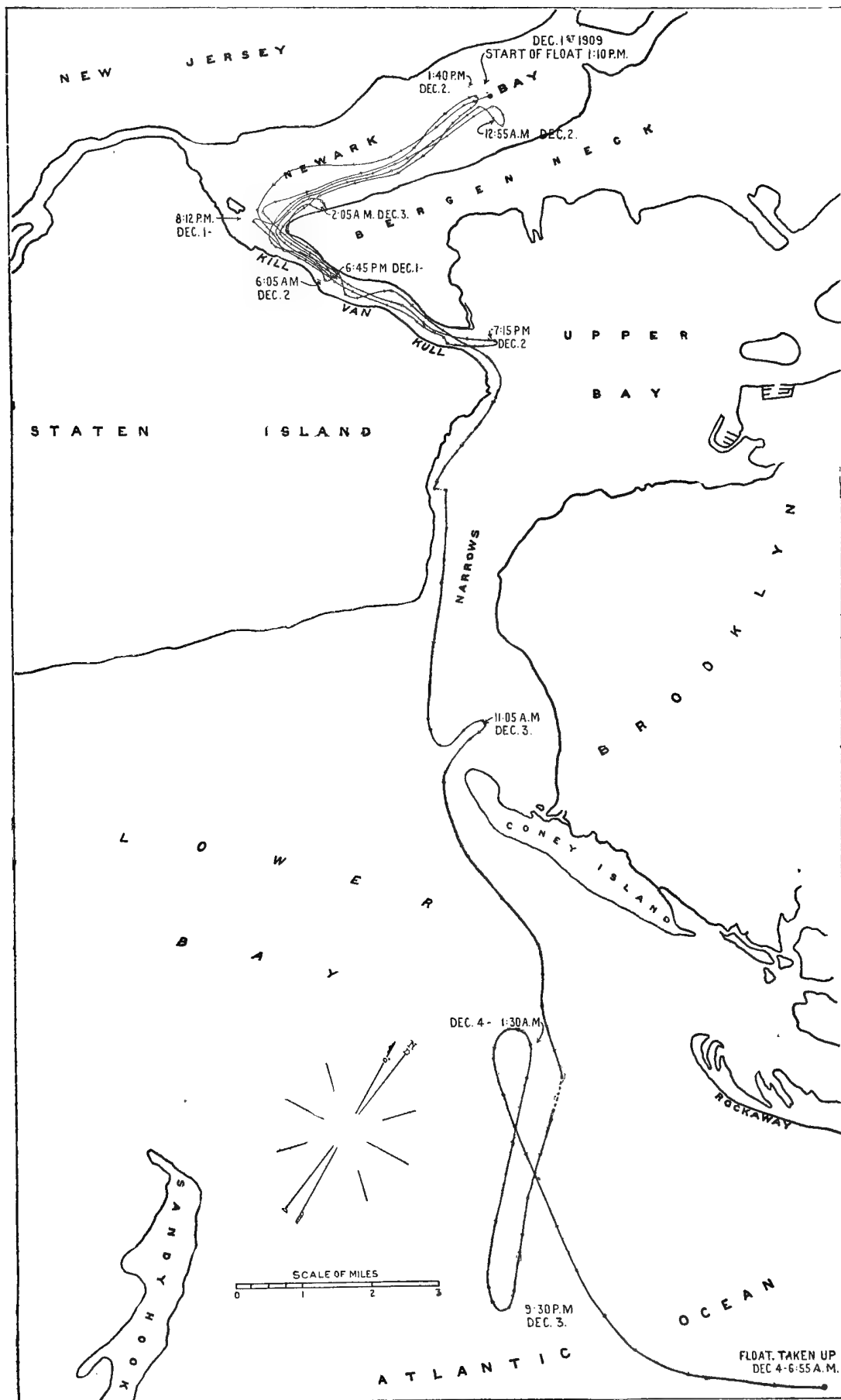
Float No. 28 traveled from near Robbins Reef westerly through the Kill van Kull 5.27 miles in 4 hours 38 minutes at a mean velocity of 1.68 mile per hour.

Float No. 40 traveled from the mouth of the Joint outlet sewer in Elizabethport up the Arthur Kill to a point one-half mile above the Central Railroad of New Jersey bridge across Newark bay and about 500 feet from the west shore, a distance of two and three-fourth miles, in three and one-half hours.

Float No. 41 traveled from the mouth of the Joint outlet sewer in the Arthur Kill to a point one-half mile above the Central Railroad of New Jersey bridge across Newark bay about 1,500 feet from the west shore, a distance of 3.5 miles, in 3 hours 55 minutes.

Float No. 42 traveled in the Arthur Kill on the ebb current from the mouth of the Joint outlet sewer, passing east of Prall's Island to a point opposite the Rahway river, a distance of 3.1 miles, in 2 hours 55 minutes.

Float No. 43 was set adrift at the bridge near the mouth of the Passaic river just before the beginning of the ebb current. It drifted toward the east shore of Newark bay, where it went ashore and was reset near the bell buoy. It reached Bergen Point 5 hours 20 minutes after starting, having traveled 6.1 miles in 6 hours 15 minutes.



Path of a Float in the Lower Bay and the Upper Bay and the Kill van Kull and Newark Bay

Float No. 44 was set adrift at the mouth of the Joint outlet sewer just before the beginning of the ebb current. It went north nearly to the railroad bridge and then southerly to Tufts Point, when the tide turned. A strong northwest wind blew it ashore, so that it had to be reset seven times. The distance covered during the ebb current was 5.75 miles in 6 hours 10 minutes.

Float No. 45 was set adrift at the mouth of the Joint outlet sewer at slack low water. It traveled across the mouth of Newark bay to Bergen Point, where it ran ashore, having drifted 3.05 miles in 4 hours 50 minutes.

Float No. 56 was set out in Newark bay near Passaic Light December 1, 1909, at 1.10 P. M. It passed Shooters Island at 5 P. M. and at 6.45 P. M. reversed its direction opposite Starin's shipyard, Port Richmond. It oscillated between this point and Passaic Light until 5.15 P. M., December 2, when it passed down stream and out of the mouth of the Kill van Kull, reversing its course at 7.50 P. M. to a westerly direction. The flood current carried it to the Central Railroad of New Jersey bridge by 1.50 A. M., December 3, and by the end of the next ebb, 9.55 A. M., it had passed through the Narrows to Norton Point.

Float No. 61 was set out opposite the outlet of the Joint trunk sewer at 11.55 A. M., December 16, 1909, near the end of the flood current. Reversing just north of the railroad bridge it drifted to Smoking Point, six and one-half miles, by 6.40 P. M., thence on the flood to the north end of Prall's Island by 12.55 A. M. December 17; thence to Tufts Point by 5.55 A. M. and from here eight miles to a point beyond Corner Stake Light at the mouth of Newark bay at 1.30 P. M. It remained within a mile of this point until 1.30 A. M. December 18, when it entered the Kill van Kull and was picked up at West New Brighton at 2 A. M.

From these experiments it seems fair to infer that:

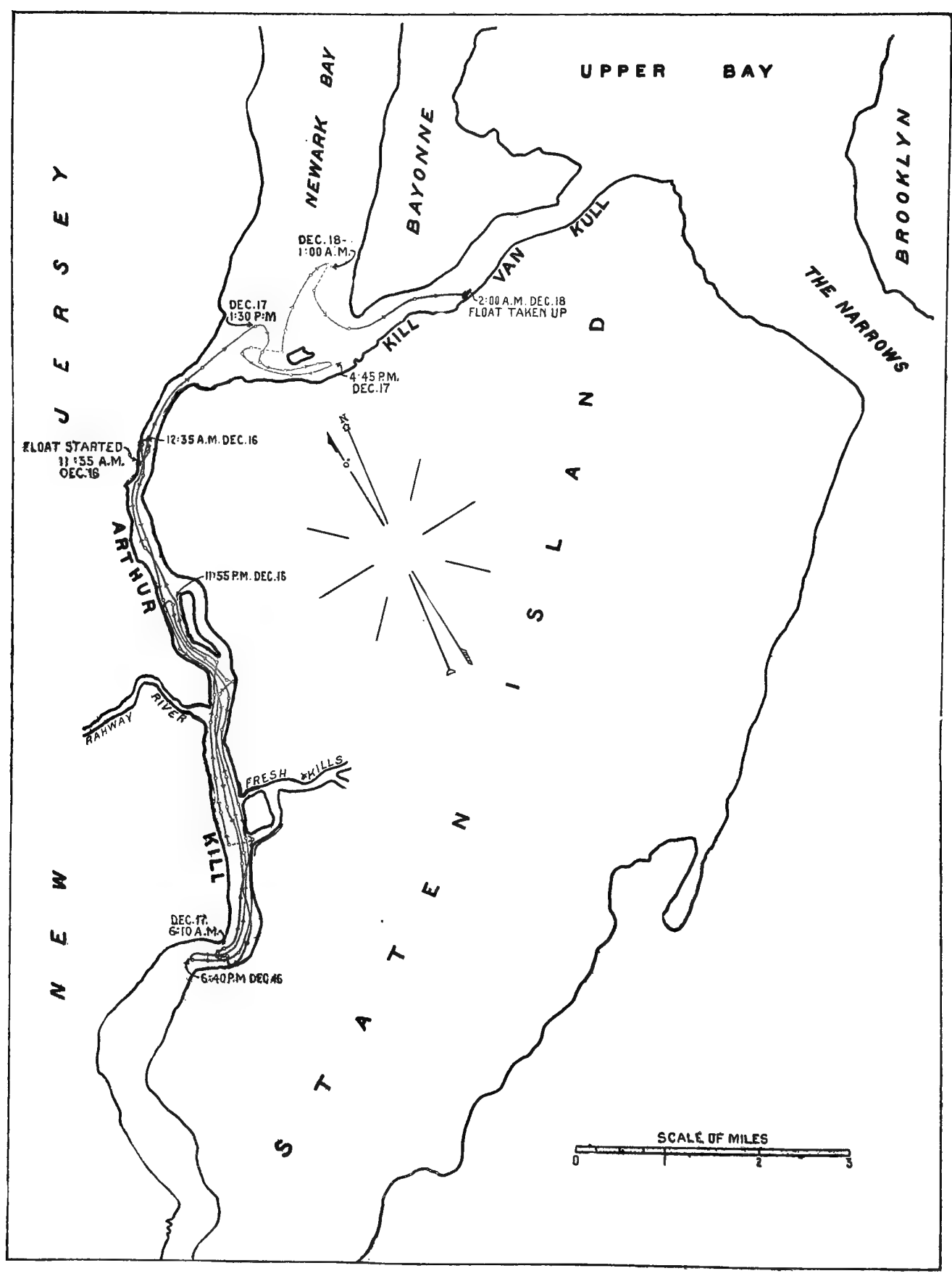
1. Floating material may remain during several tidal cycles in Newark bay or in the Arthur Kill.

2. The distance traveled on one tide was about six miles at a mean rate of one mile per hour.

3. During certain conditions of tide and wind the resultant flow of the Arthur Kill is toward the Kill van Kull.

4. The distance traveled during a single tide in Newark bay may be taken as four or five miles, with a mean velocity of about 0.8 mile per hour.

5. Floating matter will be carried in the channel through the Kill van Kull in from one and one-fourth to three hours, depending on the stage of tide, at a mean velocity of from one to two miles per hour. Maximum velocities of three miles per hour may be expected.



Path of a Float in Arthur Kill and Newark Bay and Kill van Kull

Lower Bay. There were eight float experiments made in the Lower bay in 1907, one in 1908 and four in 1909.

A float on February 23, 1907, passed out through the Narrows at 10.45 A. M. and at 2 P. M. arrived at slack water just south of Romer Shoal. It covered seven and one-half miles in three and one-fourth hours at a mean rate of 2.3 miles per hour.

A float on February 26, 1907, passed through the Narrows at 12.50 P. M. After traveling six and one-half miles it reversed its direction in the Ambrose channel at 4 P. M., having drifted at the rate of two miles per hour.

A float on March 4, 1907, passed the Narrows at 3.45 P. M. It drifted six and one-half miles in two hours at a rate of three and one-fourth miles per hour and arrived at slack water close to the point reached by the float of February 26 in the Ambrose channel.

A float on April 13, 1907, was set out in Ambrose channel east of West Bank at 7.45 A. M. In 2 hours 45 minutes it reversed its direction in the Narrows, having gone five and one-fourth miles at an average speed of 1.9 mile per hour.

A float on July 9, 1907, passed the Narrows at 12.55 P. M., passed to the east of West Bank Light at 3.05 P. M. and then drifted four and one-fourth miles southwest in spite of a westerly wind. It had traveled six and three-fourth miles in four hours 5 minutes at a mean rate of one and two-third miles per hour.

Float No. 55 passed the Narrows November 29, 1909, at 3.25 P. M. It reversed its direction near West Bank at 7.40 P. M., drifted northerly three and one-half miles with the flood and then six and one-fourth miles down the Ambrose channel. From there the flood tide carried it westerly six and one-half miles in about 6 hours 20 minutes. Then it was taken up and 46 minutes later set adrift one and one-half mile southwest of Romer Shoal at slack tide. From there it drifted southeasterly past Sandy Hook and around Scotland Lightship and then four miles southerly. In all it had traveled eleven and three-fourth miles in 7 hours 24 minutes at an average rate of 1.6 mile per hour.

Float 56 passed the Narrows December 3, 1909, at 7.35 A. M. At 9.55 the tide turned when the float was a mile northwest of Norton Point. The flood carried the float but one and one-half mile up Gravesend bay. On the following ebb it drifted six miles in 7 hours 20 minutes in a southeasterly direction to a point off Rockaway Point. It was then taken up and reset in 47 minutes five-eighth mile to the south, after which it drifted five and three-fourth miles further in 2 hours 18 minutes. Here the current reversed its course and the float traveled on the flood three and one-fourth miles in four hours. It then drifted eight miles southerly and then easterly

for 5 hours 25 minutes. It was taken up three and one-half miles south of Rockaway Beach.

Float 57 was set out in the Narrows December 7, 1909, at 10.55 A. M. It drifted southerly two miles, then northerly to a point off St. George ferry, about four and one-half miles in six and one-half hours. It then drifted to Norton Point, six and one-fourth miles, in 4 hours 20 minutes. The float remained within a mile of Norton Point during the following flood current and then drifted six miles in six and one-half hours toward Rockaway Point.

These experiments were taken to indicate that:

1. Floating matter is not likely to drift back into the Upper bay if it has passed six or eight miles below the Narrows.
2. Under certain conditions it may travel westerly toward Raritan bay to a point south of Great Kills, but ordinarily it will pass out to sea in a southeasterly direction.
3. Floating matter passing out through the Narrows frequently passes close to Norton Point and may be diverted into Gravesend bay during the period of the flood current.
4. The velocities of the currents in the Lower bay are very variable, but the mean velocity for a tidal period does not often exceed two miles per hour.

Jamaica Bay. No experiments with floats were made by the Metropolitan Sewerage Commission in Jamaica bay, although the drift of the material carried by the current at certain sewer outlets was studied by following small packages of excelsior immersed in the water.

Two sets of float observations were made in the vicinity of Rockaway Inlet, the first in December, 1906, and January, 1907, by the Jamaica Bay Improvement Commission and the second in December, 1908, by the Corps of Engineers, United States Army.

The Jamaica Bay Improvement Commission set out two floats on the flood current near Rockaway Point December 27 and December 28, 1906, each of which was followed about two and one-fourth miles, one toward Beach channel and the other toward Big Fishkill channel. A third was set out January 7, 1907, just northeast of Barren Island and was followed for 1.34 mile in a northerly direction.

Three floats were set out in Beach channel December 29, 1906, and January 2 and January 3, 1907, just north of Rockaway Beach, and followed 3.54, 3.57 and 4.80 miles, respectively, to Rockaway inlet on the ebb current. A fourth was set out west of Nestepol Island January 7, 1907, and drifted southerly 1.25 miles.

The United States Corps of Engineers set out five floats December 17, 1907, on the flood current about two miles from Rockaway Point and within a mile of Rock-

away Beach. These all rounded close to Rockaway Point and drifted eastward near the shore. Five more were set out just off Rockaway Point and were followed about three miles toward Beach channel.

Three were set adrift on the ebb current just north of Rockaway Beach and about one and one-half miles east of the point. These rounded the point and continued in a southwesterly direction.

These experiments were taken to indicate that:

1. The main tidal current enters and leaves Jamaica bay close to Rockaway Point.
2. The flood current running westerly along the south shore of Rockaway Beach and after rounding the point generally keeps close to the northerly shore of the beach, running toward Beach channel. Material entering on the flood current may, however, pass northerly to the east of Barren Island and up Big channel or across Nova Scotia bar and up Big Fishkill channel.
3. The ebb currents from these channels meet near Barren Island and in passing the inlet are diverted in a southerly direction.
4. The maximum flood currents noted outside Rockaway Point were from 1 to 1.2 miles per hour.
5. The maximum flood currents noted in Jamaica bay were from 2.7 to 3.4* miles per hour.
6. The maximum ebb currents noted in Jamaica bay were about three miles per hour.**

RELIABILITY OF RESULTS

Remembering that the motion of a surface float in the channel represents a maximum rather than a mean velocity of the water, and taking into consideration the effect of wind, which was always noted, the calculated velocities here reported are believed to be correct for the conditions of tide and land water which was flowing down the rivers at the time of the experiments.

In narrow streams, such as the Harlem river, the float sometimes drifted ashore or had its course interrupted by bridge piers, docks or passing vessels. In other cases eddies or a winding channel increased the length of the float's path.

To obtain the true maximum velocity of the stream it would be necessary to increase the observed velocity because its path is more winding than the main thread of the current. On the other hand it should be decreased on account of local deviations due to piers, vessels, etc. But with the observed data, taken in connection with the plotted courses, the results arrived at are probably reliable for the conditions which existed. The value of the records in deducing general conclusions depends largely on their number.

*East of Barren Island.

**Southwest of Barren Island and in Rockaway inlet.

SECTION II

CURRENT OBSERVATIONS

Several sets of current observations were made in order to ascertain whether the velocities which prevailed at certain points were adequate to prevent deposition of detritus or sludge. The points selected were at the proposed Passaic valley sewer outlet near Robbins Reef, at three points on the Jersey Flats, in the Upper bay and at Rockaway inlet.

METHODS AND RESULTS OF OBSERVATIONS

To determine the velocity a double can float was set adrift from a boat anchored at the chosen location and the period of time was observed during which the float was carried 100 feet by the current. This was done for different depths by adjusting the length of wire connecting the two cans. The velocity so determined was assumed to be that of the water at the depth of the top of the lower can. Determinations of velocity at depths of 20 feet or more were subject to error in timing of perhaps two or three seconds when taken for velocities of over two feet per second, as it was not practicable to start both floats in a vertical line. The consequence was, that when the top float was set adrift its motion was accelerated by a pull forward of the lower float, which had already reached an advanced position. This tendency was in part avoided by allowing the pair of cans to drift a short distance before timing, so that the recorded results are believed to be substantially correct, even at depths of 40 feet.

The direction of the current was observed by sighting to the float with an azimuth compass.

Robbins Reef. Before taking up these experiments the surface velocity had been observed in connection with the float experiments at the location at different stages of the tide, as shown in Table I.

TABLE I
VELOCITIES OF SURFACE CURRENTS AT ROBBINS REEF

Time after high water at Governors Island	Date	Current	Velocity feet per second
1 hour, 20 minutes.....	September 25, 1908	Flood	1.2
2 hours, 30 minutes.....	September 22, 1908	Ebb	0.6
2 hours, 50 minutes.....	March 4, 1907	Ebb	2.2
3 hours, 0 minutes.....	June 26, 1907	Ebb	3.7
3 hours, 20 minutes.....	October 1, 1908	Ebb	0.2
3 hours, 40 minutes.....	July 8, 1907	Ebb	2.6
3 hours, 50 minutes.....	February 26, 1907	Ebb	2.2
3 hours, 50 minutes.....	July 9, 1907	Ebb	2.2
5 hours, 45 minutes.....	September 18, 1908	Ebb	2.8

TABLE I—*Continued*

Time after low water Governors Island	Date	Current	Velocity feet per second
0 hours, 40 minutes.....	September 17, 1908	Ebb	2.6
2 hours, 0 minutes.....	September 16, 1908	Ebb	2.1
3 hours, 0 minutes.....	March 5, 1907	Flood	1.5
4 hours, 0 minutes.....	September 28, 1908	Flood	1.9
4 hours, 15 minutes.....	October 1, 1908	Flood	0.3
4 hours, 30 minutes.....	September 29, 1908	Flood	0.7
5 hours, 0 minutes.....	September 26, 1908	Flood	1.7

Being taken on different days these fail to show relative velocities on any one tidal cycle, but they do show velocities that may occur at the times specified. The velocity at times is seen to be very low, but this may in part be offset by the probability that at such times higher velocities may exist at lower depths.

The depth at Robbins Reef, which is on the edge of the main channel, is about 50 feet at low water.

Two series of velocity observations were taken, each covering practically the 12 lunar hours of the tide—one at or near the time of spring tides and one at or near the time of neap tides—with the intention of showing the differences in velocity to be expected from the phase of the moon. As it was impracticable to take most of the observations on the exact day of springs or neaps the range observed is probably somewhat less than the extreme due to this cause.

The velocities observed each day have been plotted with reference to the time of high water at Governors Island, and the result of each series shown complete in one diagram. Where the same period of the tide has been observed on different days the mean velocity for the observations at this period has been taken.

Velocities were observed near the surface, mid-depth and bottom—generally 4, 20 and 40 feet from the surface. From an examination of the resultant diagrams we find that the velocities shown in Tables II and III may be expected at this location.

TABLE II
VELOCITIES OF CURRENTS AT SPRING TIDES AT ROBBINS REEF

	a. Slack High Water			b. Ebb Current		
	4	20	40	4	20	40
Depth in feet	4	20	40	4	20	40
Hours after high water, Governors Island.....	2	2	2	5	4.5	4 to 6
Velocity in feet per second	0.6	0.4	0.6	3.6	3.8	3.4 to 3.5

DATA COLLECTED

TABLE II—*Continued*

	c. Slack Low Water			d. Flood Current		
Depth in feet	4	20	40	4	20	40
Hours after high water, Governors Island.....	9.5	9.5	9.5	12.0	0	0
Velocity in feet per second	0.8	0.6	0.4	3.3*	2.8*	2.6*

TABLE III

VELOCITIES OF CURRENTS AT NEAP TIDES AT ROBBINS REEF

	a. Slack High Water			b. Ebb Current		
Depth in feet	4	20	40	4	20	40
Hours after high water, Governors Island.....	2.5	3.0	3.0	6.0	5.5	6.0
Velocity in feet per second	0.4	0.3	0.2	2.3	2.5	2.3
	c. Slack Low Water			d. Flood Current		
Depth in feet	4	20	40	4	20	40
Hours after high water, Governors Island.....	9.0	9.0	8.0	1.0	0.5	0.5
Velocity in feet per second	0.4	0.4	0.0	1.3	1.7	1.8

* Interpolated. Record incomplete.

On the Jersey Flats. The method used on the Jersey Flats was the same as that followed at Robbins Reef, the particular object being to determine the velocities near the bottom that may produce erosion.

South of the Pennsylvania Railroad terminal the velocities were observed two feet from the surface and about two feet from the bottom, the depth at low water being about seven feet. The resultant curve was plotted from the work of several days, irrespective of the phase of the moon. The results are given in Table IV.

TABLE IV

MID-DEPTH VELOCITIES OF CURRENTS IN FEET PER SECOND SOUTH OF THE PENNSYLVANIA TERMINAL, UPPER NEW YORK BAY

Hours after high water Governors Island	Velocity	Hours after high water Governors Island	Velocity	Hours after high water Governors Island	Velocity	Hours after high water Governors Island	Velocity
Slack low water		Flood current		Slack high water		Ebb current	
2.0	.40	4.5	.80	7.0	.15	12.0	1.15

Northeast of the Pennsylvania Railroad terminal the observations were taken in a similar manner and the depth was about the same, but the work extended over but about six hours. The results are shown in Table V.

TABLE V

MID-DEPTH VELOCITIES OF CURRENTS IN FEET PER SECOND NORTHEAST OF THE PENNSYLVANIA TERMINAL, UPPER NEW YORK BAY

Hours after high water Governors Island	Velocity	Hours after high water Governors Island	Velocity	Hours after high water Governors Island	Velocity	Hours after high water Governors Island	Velocity
Slack low water 1½	0.05	Flood current ....	....	Slack high water 7.0	0.10	Ebb current 11.0	1.10*

* Record incomplete. The maximum velocity probably occurred later than this.

Off Black Tom Island velocities were observed about three feet below the surface only, the depth at low water being but about six feet. See Table VI.

TABLE VI

VELOCITIES OF CURRENTS AT A DEPTH OF THREE FEET UNDER THE SURFACE IN FEET PER SECOND OFF BLACK TOM ISLAND, UPPER NEW YORK BAY

Hours after high water Governors Island	Velocity	Hours after high water Governors Island	Velocity	Hours after high water Governors Island	Velocity	Hours after high water Governors Island	Velocity
Slack high water 11.7	0.00	Ebb current 2.50	1.15	Slack low water 7.7	0.00	Flood current 8.5	0.80

Rockaway Inlet. Velocities were observed at Rockaway Inlet in the channel between Rockaway Point and Plum Island at about 0.2 and 0.8 of the depth, which was ordinarily between 40 and 45 feet, with the results shown in Table VII.

TABLE VII

MEAN VELOCITY OF CURRENTS IN FEET PER SECOND IN ROCKAWAY INLET

Hours after high water, Governors Island.....	0.5	3	7	9
Tidal current.....	Slack	Ebb	Slack	Flood
Mean velocity.....	0.0	3.4	0.0	2.1

CHAPTER V

SEWERAGE AND SEWAGE DISPOSAL WORKS OF THE MUNICIPALITIES WITHIN THE METROPOLITAN DISTRICT

The natural growth of a great population around the waters of New York harbor has resulted in their defilement by sewage and manufacturing wastes sufficiently to attract public attention.

In order to present an accurate picture of these conditions the sewerage works and conditions surrounding the disposal of the sewage of all the important cities and towns in the metropolitan district will be described in the following pages.

SECTION I

SEWERAGE OF THE CITY OF NEW YORK

BOROUGH OF MANHATTAN

GENERAL FEATURES AND CONDITIONS

Principal Topographical Characteristics. The Borough of Manhattan is an island having an average width of nearly $1\frac{3}{4}$ miles, an extreme length of $13\frac{3}{4}$ miles and a total area of a little more than 22 square miles. Its main topographical feature is a ridge following approximately the line of Broadway from the Battery to Central Park, and thence parallel to and about one-half mile east of the Hudson river to the northern line of the city. This ridge is broken through at Manhattan street, but runs thence continuously to Spuyten Duyvil creek. Generally speaking, all the district lying east of the dividing ridge, except that portion which drains out through Manhattan street, drains into the East and Harlem rivers and all the territory lying west of the ridge drains into the Hudson river. In most places the slopes toward the surrounding waters are relatively steep and few serious difficulties have been encountered with respect to securing proper grades for the sewers excepting in certain localities along the water-front.

Originally the topography of Manhattan Island was more or less irregular, the ground rising gradually, except in a few localities, towards the central ridge above described. With the development of the city the irregularities of the shore line have been straightened out by the filling up of bays, and by extending the dock line to deep water, and there has thus been formed a strip of land from 300 to 500 feet wide, with its surface about 8 to 10 feet above mean tide around a considerable part of the island.

Account of Growth of Sewerage System. From 1676 until 1849 the sewers and drains of New York were built without definite plan, the larger and more important by the Street Commissioner, the smaller ones, usually rectangular culverts with stone sides and tops, by property owners to drain their lots.

Up to 1849 some 70 miles of sewers had been built; these have now (1909) been mostly replaced by more modern structures. The sewer in Canal street, built between 1805 and 1810, is the principal one belonging to this early period still in use; it is in bad repair, however, and should be rebuilt.

When a new water supply was furnished the City from the Croton watershed in 1842 improved plumbing and greater sanitary conveniences were extensively introduced; the effect of this is seen in the greater care given in the construction of sewers dating from that time.

The Croton Aqueduct Department, organized under Act of the Legislature of April 11, 1849, superseded the Board of Water Supply Commissioners and the Croton Aqueduct Board, who until then had been charged with furnishing the City with water. Under the Aqueduct Department was placed a Bureau of Pipes and Sewers, in charge of a Water Purveyor, the Bureau having complete control over the construction of sewers after the authorization of their construction by the Board of Aldermen. Two years later the title of the Bureau was changed to the Bureau of Sewers and Drains, the Water Purveyor still remaining the executive head.

In 1865 the State Legislature passed a general sewerage Act which required plans for each sewerage district to be filed before the sewers were constructed and their cost assessed in the district; and under the influence of this Act attention was more generally given to the matter of sizes, grades and proper materials of construction. This law is still in force. Under its provisions plans were made for proper sewerage for the territory south of One Hundred and Fifty-fifth street by Alfred Craven, Chief Engineer of the Croton Aqueduct Board, and in later years by the Department of Public Works for the territory north of One Hundred and Fifty-fifth street.

Owing to the many changes which have been made, the plans for the sewerage of one district having been altered more than 150 times, no correct plans of any of the older sewerage districts are obtainable.

Up to 1865, the time when the sewerage Act went into effect, there were about 206 miles of sewers in use in the city. Most of these were built without any definite plan by private individuals or by the City; the records of their locations, sizes and grades are consequently incomplete and unreliable. The sewers are often of improper sizes and materials, on bad foundations and out of line and grade.

Mr. Craven had charge of the sewers and originated many improvements in details of construction between 1865 and 1868, at which time he was succeeded by Gen. Geo. S.

Greene, who remained in charge until April 10, 1870, when by Legislative action the control of the sewers was taken from the Croton Aqueduct Department and given to the newly organized Department of Public Works, with Mr. Stevenson Towle as engineer in charge of the sewer department. At that time there were about 261 miles of sewers in the city.

Mr. Towle began immediately an examination of the sewers and pushed it as rapidly as circumstances permitted. In 1873 he surveyed and examined about 100 miles of the old sewers, finding many completely unserviceable, generally too large, filled with deposits which generated acids and destroyed the materials of construction. Many also had settled with their tops below low water and every rise of tide would cause foul gases to be driven back through the traps into the houses.

Many of the earlier brick sewers built about 1850 were circular in section, about 4 feet in diameter, and laid with lime mortar. Frequently no mortar was used in the invert, or lower portion, in order that the sewage might soak away into the ground as much as possible.

About 1860 the Department adopted an egg-shaped section for the sewers, most of those built during that period being about 4 feet high and 3 feet or 2 feet 8 inches wide. This proved to be an advantageous change, as the greater concentration of flow made stoppages from deposits less frequent. The first vitrified pipe sewers were laid in 1864, about 60 miles having been laid prior to 1869.

The earlier sewers usually terminated at the shore line, but were extended from time to time as the streets were graded out to the bulkhead line, the almost invariable result being the settlement of this filling and consequent breaking and disrupting of the sewers.

In 1888 Mr. Rudolph Hering was engaged by Gen. John Newton to report on the condition of New York's sewers. The final unpublished report, addressed to Mr. Thos. F. Gilroy, Commissioner of Public Works, was dated May 31, 1889. It contained much original data regarding the choice of proper sizes for storm water sewers in New York, the diagrams being based on continuous discharge measurements of the Sixth avenue sewer at Third street, which drained 221 acres of the Minetta lane district. These data form the basis of present estimates of quantities of storm water to be taken care of by sewers in Manhattan. The report covered also, among other things, recommendations for increasing the efficiency and lowering the cost of the work of cleaning the sewers.

Under the authority of Chapter 378 of the Laws of 1897, the Department of Public Works was changed, and the charge of the sewers placed under a Commissioner of Sewers, Mr. Horace Loomis being appointed Chief Engineer.

Later, under the Greater New York Charter, the sewers were placed under the supervision of the Borough Presidents, with a Superintendent of Sewers and Chief Engineer of Sewers in each borough; Mr. Horace Loomis was further retained as the Chief Engineer of the Bureau for the Borough of Manhattan. Under Mr. Loomis' direction, much good work has been done towards improving and remodeling the sewers of New York, though some of his recommendations have not been acted upon.

Practically all the old sewers built prior to 1849 have been replaced with new ones, or put in repair, and the sewer outlets have, where piers exist, with but few exceptions, been extended from the bulkhead to near the pierhead line. The present policy of the Bureau favors, instead of the construction of intercepting sewers discharging at a few large outlets, the discharge, as far as practicable, of each small sewer through a separate outfall. The intercepting sewers, owing to the light grades obtainable along the level river front, are regarded as elongated cesspools and deposit sewers.

SEWERAGE WORKS

Sewers. The sewers are, as a rule, of brick, and egg-shaped in section, the most common size being about 4 feet high and 3 feet wide. Some of the newer sewers built in recent years, however, are of concrete.

Manholes with perforated covers, for ventilation, are provided at frequent intervals, and catch basins are built at the corners of the blocks, where needed to divert the water from the street gutters into the sewers.

The simplicity of the drainage problem has led naturally to the development of a sewerage system upon the combined plan; that is, upon a plan in which house sewage and storm water are carried in the same sewers. All the drainage districts are practically independent.

The outfalls number about 172, and provide sewerage for the entire borough, which has an area of 14,000 acres. The Hudson river receives, through 53 outlets, the drainage from 5,600 acres; the East river, through 68 outlets, the drainage from 3,900 acres, and the Harlem river, through 51 outlets, the drainage from 2,600 acres.

Sixty per cent. of the total city sewage is discharged from 29 outlets, the three largest being the East One Hundred and Tenth street sewer, which drains 700 acres into the Harlem river, the Manhattan street sewer discharging the sewage from 723 acres into the Hudson river, and the East Forty-ninth street sewer discharging the sewage from 616 acres into the East river. Thirteen of the 29 large outlets discharge into the Hudson, 10 into the East river and 6 into the Harlem river.

Roughly speaking, of the sewage of Manhattan, that from about 650,000 people is discharged into the Hudson river, that from about 1,087,000 into the East river, and that from 366,000 into the Harlem river.

Outfalls. Most of the sewer outfalls are placed under piers, the discharge taking place usually about 20 or 30 feet back of the end of the pier. Little trouble has, in the past, been experienced from the drifting or blowing of floating matter from the harbor into the sewers. Many of these outfalls consist of steel-banded wooden flumes carried out on the cross timbers under the piers or wharves, and strapped thereto with bands or rods.

The outlets of the Manhattan sewers, with their locations, sizes, points of discharge, areas drained and date of construction, reconstruction or repair, are as given in Table I.

TABLE I
OUTLETS OF THE SEWERS OF MANHATTAN

Location	Point of discharge	Size		Area drained Acres	When built, rebuilt or repaired
		Actual	Equivalent circular section		
Dyckman street.....	Hudson river...	5'x7'	6' 0"	354	1895
West 171st street.....	" " ...	5'x4'	4' 6"	217	1899
West 158th street.....	" " ...	.....	3' 6"	135.75	1884
West 155th street.....	" " ...	.....	1' 6"	10	
West 152d street.....	" " ...	.....	3' 0"	4.75	1876
West 149th street.....	" " ...	pipe	1' 4"	5.5	1897
West 148th street	" " ...	pipe	1' 4"	5.5	1897
West 147th street	" " ...	pipe	1' 4"	5.5	1892
West 146th street.....	" " ...	pipe	1' 4"	5.5	1893
West 145th street.....	" " ...	pipe	1' 4"	5.5	1894
West 144th street.....	" " ...	pipe	1' 4"	5.5	1899
West 143d street.....	" " ...	pipe	1' 4"	5.5	1897
West 142d street.....	" " ...	pipe	4' 0"	83.5	1875
West 138th street.....	" " ...	pipe	1' 3"	5.25	1872
West 130th street.....	" " ...	(5'x4')+(5'6"x7')	7' 8"		
West 129th street.....	" " ...	2(4'3"x5'10") bbl.	7' 0"	633.5	1891
West 115th street.....	" " ...	4'x3'	3' 6"	82.75	1882
West 108th street.....	" " ...	.....	4' 0"	65.75	1901
West 96th street.....	" " ...	With 2 outlets	[6' 0"	416	1905

TABLE I—Continued

Location	Point of discharge	Size		Area drained Acres	When built, rebuilt or repaired
		Actual	Equivalent circular section		
West 91st street.....	Hudson river...	.....	4' 0"	21.5	1883
West 80th street.....	" " ...	5'7½"x5'	5' 3"	339.5	1873
West 72d street.....	" " ...	bbl.	4' 0"	49	1903
West 66th street.....	" " ...	.....	4' 0"	505.5	1868
West 59th street.....	" " ...	bbl.	4' 0"	66.25	1876
West 56th street.....	" " ...	.....	3' 0"	44.5	1891
West 54th street.....	" " ...	3'6"x2'4"	2' 10"	19.5	1897
West 50th street.....	" " ...	bbl.	4' 0"	62.75	1902
West 48th street.....	" " ...	bbl.	4' 0"	33.5	1902
West 46th street.....	" " ...	4'x2'8"	3' 3"	11.25	1867
West 45th street.....	" " ...	4'x2'8"	3' 3"	11.25	1879
West 44th street.....	" " ...	4'x3' box, rep.	4' 0"	11.25	1904
West 43d street.....	" " ...	4'x2'8"	3' 3"	11.25	1863
West 42d street.....	" " ...	{ 7'6" cir.+6'x6' 5'6"x4'9" box }	11' 6"	434.25	1904
West 40th street.....	" " ...	5'x5' box	5' 8"	99	
West 39th street.....	" " ...	bbl.	4' 0"	8.5	1907
West 38th street.....	" " ...	pipe	1' 6"	11.25	
West 36th street.....	" " ...	bbl.	4' 0"	48	1891
West 30th street.....	" " ...	.....	4' 0"	56.5	1904
West 26th street.....	" " ...	Twin 4' 3" ell, bbl.	5' 0"	276.25	1900
West 23d street.....	" " ...	Twin 4' 6" bbl, rep.	6' 4"	152.25	1908
West 20th street.....	" " ...	2 (4' bbl.) rep.	5' 8"	118	1907
West 17th street.....	" " ...	5'x4'6"+5'x3'6" bbl.	6' 4"	169.25	1908
Little West 12th street.....	" " ...	3'6"x2'4"	2' 11"	10.75	1892
Gansevoort street.....	" " ...	.....	4' 0"	23	1901
Jane street.....	" " ...	4' cir.+4' cir.+4'x2'8"	6' 6"	53	1901
Bank street.....	" " ...	4' cir.+4' cir. 5'x5'+5'x5'	5' 8"	18.75	1901
Clarkson street.....	" " ...	5'6"x9'6"	10' 8"	468	1882
Canal street.....	" " ...	8'x16'+2 (4'x2'8")	13' 0"	242	
Vestry street.....	" " ...	5'x3'6" Ell, rep.	4' 2"	42.5	1896
Duane street.....	" " ...	.....	4' 0"	69.25	1888
Dey street.....	" " ...	.....	4' 0"	46.75	1891

TABLE I—*Continued*

Location	Point of discharge	Size		Area drained Acres	When built, rebuilt or repaired
		Actual	Equivalent circular section		
Carlisle street.....	Hudson river ...	bbl.	3' 0"	25.25	1891
Rector street.....	" " ...	bbl.	3' 0"	21	1886
Morris street.....	" " ...	bbl.	4' 0"	14.25	1905
Broad street.....	East river.....	Twin 4' bbl.	5' 8"	61.5	1906
Coenties slip.....	" "	4'6"x3' 8" Ell. bbl.	4' 0"	15.75	1892
Burling slip.....	" "	bbl.	4' 0"	58	1893
Roosevelt street.....	" "	bbl.	4' 0"	134.75	1886
Oliver street.....	" "	2 outlets	5' 8"	172.75	
Market street.....	" "	2 (3' bbl.)	4' 3"	34	1892
Jefferson street	" "	5'x5'	5' 0"	128	
Scammel street	" "	bbl.	4' 0"	25.5	1898
Jackson street.....	" "	4'x3" Ell. bbl.	3' 6"	10	
Corlears street.....	" "	5'x4' bbl.	4' 6"	14.25	1898
Grand street.....	" "	5'x4' Ell.	4' 6"	60	1898
Rivington street.....	" "	4' bbl.+5'4"	6' 0"	109.25	1898
Stanton street.....	" " .....	.....	4' 0"	45.75	1895
Houston street.....	" "	pipe	4' 0"	88.25	1880
East 3d street.....	" "	pipe	5' 0"	33.75	1893
East 4th street.....	" "	pipe	2' 6"	6	
East 5th street.....	" "	4'x2'8"	3' 4"	7.25	1850
East 6th street.....	" "	4'x2'8" egg	3' 4"	6	1895
East 7th street.....	" "	4'x2'8"	3' 4"	4.75	1855
East 8th street.....	" "	4'x4'	4' 0"	12.75	1867
East 10th street.....	" "	3'6"x2'4"	2' 11"	.....	1907
East 11th street.....	" "	3' box	3' 5"	7	1890
East 14th street.....	" "	2 (6'x7')	9' 2"	273.5	1872
East 15th street.....	" " .....	.....	3' 6"	14.75	1858
East 16th street.....	" "	5'x3'	4' 0"	15.75	1859
East 18th street.....	" "	4'x2'8" egg+6'x8'	7' 9"	188.5	1892
East 21st street.....	" "	5'x4' ell. bbl.	4' 6"	142	1905
East 23d street.....	" "	bbl.	4' 0"	64.5	1902
East 24th street.....	" " .....	.....	4' 0"	17.	1892

DATA COLLECTED

TABLE I—*Continued*

Location	Point of discharge	Size		Areas drained Acres	When built rebuilt or repaired
		Actual	Equivalent circular section		
East 26th street.....	East river.....	3'9"x4'6" bbl. rep.	4' 1"	13.25	1903
East 28th street.....	" ".....	.....	4' 0"	23.	1901
East 29th street.....	" ".....	3'2" egg	2' 6"	2.25	1886
East 31st street.....	" ".....	pipe	1' 3"	2.25	1888
East 33d street.....	" ".....	5'6"x8'	6' 9"	220.25	1894
East 36th street.....	" ".....	3'6"x2'4"	2' 11"	1.75	1899
East 37th street.....	" ".....	bbl.	3' 0"	1.75	1898
East 38th street.....	" ".....	4'x2'8" egg	3' 4"	2.25	
East 42d street.....	" ".....	.....	6' 0"	93.5	1878
East 43d street.....	" ".....	3'6"x2'6"	3' 0"	4.	1880
East 44th street.....	" ".....	3'6"x2'4"	2' 11"	8.	1902
East 45th street.....	" ".....	4'x2'8"	3' 4"	7.75	1861
East 46th street.....	" ".....	pipe	1' 3"	7.75	1868
East 47th street.....	" ".....	4'x2'8"	3' 4"	7.75	1861
East 48th street.....	" ".....	4'x2'8" rep.	3' 4"	9.25	1889
East 49th street.....	" ".....	9'x2'6"	8' 9"	616.	1854
East 53d street.....	" ".....	3'6"x2'4"	2' 8"	4.25	1875
East 54th street.....	" ".....	4'x2'8"	3' 4"	27.25	1873
East 57th street.....	" ".....	.....	2' 0"	14.	1994
East 62d street.....	" ".....	3'6" box	3' 6"	138.5	1894
East 63d street.....	" ".....	3'6"x2'4" egg	2' 11"	1.75	1897
East 64th street.....	" ".....	3'6"x2'0" egg	2' 9"	2.5	1887
East 70th street.....	" ".....	3'x2' box	2' 6"	4.	1882
East 71st street.....	" ".....	3'x2'	2' 6"	4.25	1883
East 73d street.....	" ".....	3'6"x2'0" egg	2' 9"	4.25	1890
East 74th street.....	" ".....	rep.	6' 0"	332.	1907
East 75th street.....	" ".....	3'6"x2'0"	2' 9"	4.5	1888
East 76th street.....	" ".....	3'6"x2'0"	2' 9"	4.5	1887
East 77th street.....	" ".....	3'6"x2'4"	2' 9"	4.75	1894
East 78th street.....	" ".....	3'x2'	2' 6"	4.75	1893
East 79th street.....	" ".....	44'x4'7" box rep.	5' 0"	302.	1899
East 83d street.....	" ".....	pipe	1' 3"	2.	1905

TABLE I—Continued

Location	Point of discharge	Size		Area drained Acres	When built, rebuilt or repaired
		Actual	Equivalent circular section		
East 84th street.....	East river.....	pipe	1' 4"	2.	1900
East 86th street.....	" ".....	.....	4' 0"	84.5	1895
East 89th street.....	" ".....	.....	5' 0"	57.	1871
East 90th street.....	" ".....	pipe	1' 3"	4.	1894
East 91st street.....	" ".....	pipe	1' 3"	2.25	1892
Ave. A.....	" ".....	bbl.	4' 0"	9.	1903
East 95th street.....	" ".....	.....	4' 0"	92.5	1891
East 100th street.....	" ".....	3'6"x2'4"	2' 10"	3.5	1896
East 101st street.....	Harlem river.....	3'6"x2'0" egg	2' 8"	4.25	1894
East 102d street.....	" ".....	3'6"x2'0" egg	2' 8"	4.5	1889
East 103d street.....	" ".....	3'6"x2'0" egg	2' 8"	4.5	1891
East 104th street.....	" ".....	3'6"x2'0" egg	2' 8"	4.5	1891
East 105th street.....	" ".....	3'6"x2'0" egg	2' 8"	4.5	1886
East 106th street.....	" ".....	5'6"x7'0"	6' 6"	286.	1875
East 110th street.....	" ".....	8'0"x12'0"	10' 0"	700.	1871
East 111th street.....	" ".....	3'6"x2'0"	2' 8"	3.75	1893
East 115th street.....	" ".....	pipe	1' 3"	3.75	1892
East 116th street.....	" ".....	pipe	1' 3"	4.	1892
East 117th street.....	" ".....	pipe	1' 0"	4.75	1867
East 118th street.....	" ".....	.....	4' 6"	50.75	1872
East 119th street.....	" ".....	pipe	1' 3"	6.5	1869
East 120th street.....	" ".....	.....	4' 0"	38.75	1867
East 121st street.....	" ".....	pipe	1' 3"	3.	1892
East 122d street.....	" ".....	.....	4' 0"	26.75	
East 124th street.....	" ".....	3'6"x2'4"	3' 0"	6.	1876
East 125th street.....	" ".....	4'0"x2'8"	3' 6"	61.75	1892
2d avenue.....	" ".....	3'7"x2'5"	3' 1"	9.5	1871
3d avenue.....	" ".....	4'0"x2'8"	3' 5"	63.	1861
East 135th street.....	" ".....	4'9"x5'0"	5' 0"	184.75	1880
East 136th street.....	" ".....	pipe	1' 0"	1.5	1894
East 140th street.....	" ".....	3'6"x2'4" egg	2' 10"	21.75	1896
East 141st street.....	" ".....	pipe	1' 3"	7.75	1894

TABLE I—*Continued*

Location	Point of discharge	Size		Area drained Acres	When built rebuilt or repaired
		Actual	Equivalent circular section		
East 142d street.....	Harlem river....	4'0"x2'8"	3' 5"	19.	1903
East 143d street.....	" "	3'6"x2'4"	2' 10"	4.25	1907
East 144th street.....	" "	3'6"x2'4"	2' 10"	4.25	1907
East 145th street.....	" "	pipe	1' 0"	2.5	1901
East 145th street.....	" "	6'0"x5'0"	5' 6"	9.5	1901
East 147th street.....	" "	4'0"x2'8"	3' 5"	4.75	1905
Lenox (6th) avenue.....	" "	2 42" pipes into outlet	5' 0"	47.	1903
East 151st street.....	" "	.....	9' 6"	330.	1903
7th avenue.....	" "	4'0"x2'8"	3' 5"	18.75	1900
East 155th street.....	" "	pipe	1' 3"	6.	1888
8th avenue.....	" "	4'0"x2'8"	3' 5"	42.	1887
East 167th street.....	" "	.....	4' 0"	94.75	1893
East 178th street.....	" "	.....	4' 0"	117.	1896
East 201st street.....	" "	.....	4' 0"	196.	1900
East 203d street.....	" "	3'6"x2'4"	2' 10"	8	1907
East 204th street.....	" "	3'6"x2'4"	2' 10"	2	1907
East 205th street.....	" "	.....	4' 0"	14	1901
East 206th street.....	" "	3'6"x2'4"	2' 10"	3	1908
East 207th street.....	" "	3'6"x2'4"	2' 10"	12.5	1907
East 209th street.....	" "	.....	4' 0"	14.75	1902
East 211th street.....	" "	.....	4' 6"	30	1907
East 213th street.....	" "	4'0"x2'8"	3' 4'	8	1906
East 214th street.....	" "	3'6"x2'4" egg	2' 10"	8	1907
East 215th street.....	" "	3'6"x2'4" egg	2' 10"	4	1908
East 216th street.....	" "	5'0"x'40"	4' 6"	13	1906
Broadway.....	Ship canal....	.....	4' 0'	43.75	1902

The following outlet sewers were reconstructed, or were in progress, in 1909 :

1. Outlet sewer under Pier 15, East river.
2. Outlet sewer overflows and connections at Forty-second and Forty-third streets, North river.
3. Outlet sewers in Twenty-eighth and Twenty-ninth streets, East river.
4. Outlet sewer between One Hundred and Thirty-fourth and One Hundred and Thirty-fifth streets, Harlem river.

The following were under construction at the end of that year :

1. A sewer under Pier 40, Hudson river.
2. A barrel sewer under pier at foot of Twenty-sixth street, East river.
3. The extension of the outlet sewer at the foot of One Hundred and Eighteenth street, Harlem river.

Of the older outfalls the greater part are at so low an elevation as to be submerged at high tide, thus sealing up the end of the sewer and interfering with ventilation as well as favoring the formation of deposits by checking the velocity of the flow in the sewer.

The present method of discharging sewage into the harbor along the Manhattan water front is unsatisfactory; it creates nuisances along the water front; it pollutes the public bathing establishments; it surrounds the City's recreation piers and the slips and docks whence steamers sail for foreign and domestic ports with disagreeable odors; and it produces unsanitary conditions in the vicinity of market places where vegetables, fruits and other infectable food products are exposed for sale, and where, as a matter of course, flies, rats and other infection spreading vermin abound.

At present the discharge of sewage takes place practically at the surface of the harbor water, with an imperfect admixture with incoming tidal streams. The sewage floats around on the surface of the harbor, in the slips, under docks, piers and buildings; coats the surfaces of walls, piles and piers with grease and filth; finally it is carried away by the ebbing currents, still upon the surface, but much diluted and scattered.

This is a primitive method unsuited to a large city with many miles of water front on a tidal harbor. The physical aspects of the problem are simple and the selection of the proper details of construction to avoid such results is a matter of local expediency and cost in each case.

Ventilation. The ventilation of the sewers is accomplished through the perforations in the manhole covers in the streets. The air within the sewer is changed and refreshed largely by the changing volume of flow in the sewer which, when increasing, drives out some of the air through the perforations, and when decreasing, draws in fresh air from the street. Traps are used on all house connections. In some portions of the city, notably in the older parts near the water front, the ventilation is very defective as a result of the settlement of the sewers, the entrance of tide water, and submergence of the outlets. Nuisances frequently result in many districts where steam and hot water are discharged into the sewers, hot vapors rising to the upper sections and issuing through the manhole covers disseminating odors of cooked sewage through the neighborhood. Improvements in this direction are imperatively needed.

Growth of System. The growth of Manhattan's sewerage system since 1849, year by year, is exhibited in Table II.

TABLE II
GROWTH OF MANHATTAN'S SEWER SYSTEM

Year	Miles of Sewers Built Each Year	Total Miles of Sewers	Year	Miles of Sewers Built Each Year	Total Miles of Sewers
Before 1849	69.7	69.7	December 1866.....	7.0	209.0
December, 1849.....	3.3	73.0	" 1867.....	19.9	228.9
" 1850.....	11.7	84.7	" 1868.....	15.6	244.5
" 1851.....	11.9	96.6	" 1869.....	16.3	260.8
" 1852.....	12.4	109.0	April, 1871.....	15.1	275.9
" 1853.....	13.9	122.9	" 1872.....	12.1	288.0
" 1854.....	13.9	136.8	" 1873.....	17.3	309.3
" 1855.....	7.3	144.1	December, 1873.....	13.7	322.0
" 1856.....	9.3	153.4	" 1874.....	17.0	339.0
" 1857.....	2.0	155.4	" 1875.....	12.7	351.7
" 1858.....	6.8	162.2	" 1876.....	4.9	356.6
" 1859.....	7.9	170.1	" 1877.....	5.8	362.4
" 1860.....	7.0	177.1	" 1878.....	6.8	369.2
" 1861.....	5.5	182.6	" 1879.....	2.4	371.6
" 1862.....	3.7	186.3	" 1880.....	6.1	377.7
" 1863.....	3.8	190.1	" 1881.....	5.4	383.1
" 1864.....	4.5	194.6	" 1882.....	8.0	391.1
" 1865.....	7.4	202.0	" 1883.....	7.0	398.1

Avg. 11.76

Avg 17.58
Miles built per year

Avg. 5.2

TABLE II—Continued

Year	Miles of Sewers Built Each Year	Total Miles of Sewers	Year	Miles of Sewers Built Each Year	Total Miles of Sewers
December 1884.....	10.3	408.4	December 1897.....	10.9	483.1
" 1885.....	2.0	410.4	" 1898.....	1.0	484.1
" 1886.....	3.8	414.2	" 1899.....	4.9	489.0
" 1887.....	7.3	421.5	" 1900.....	5.6	494.6
" 1888.....	7.6	429.1	" 1901.....	2.3	496.9
" 1889.....	4.6	433.7	" 1902.....	3.7	500.6
" 1890.....	4.2	437.9	" 1903.....	4.5	505.1
" 1891.....	6.4	444.3	" 1904.....	2.5	507.6
" 1892.....	5.1	449.4	" 1905.....	3.8	511.4
" 1893.....	6.4	455.8	" 1906.....	2.4	513.8
" 1894.....	6.2	462.0	" 1907.....	4.2	518.0
" 1895.....	6.0	468.0	" 1908.....	2.7	521.7
" 1896.....	4.2	472.2			

The sewerage system is estimated to have cost upwards of \$26,000,000, but no records are available showing the actual amounts laid out, particularly in the earlier years. The following sewers were built during 1909 by private parties and corporations having underground interests and by the Sewer Bureau:

	Feet.
1. By private parties under Sewer Bureau supervision.....	1,922
2. By the Hudson and Manhattan Railroad Company.....	711
3. By the New York Central and Hudson River Railroad Company...	86
4. By the Pennsylvania Tunnel and Terminal Company.....	705
5. By the Public Service Commission.....	8,423
6. By the Bureau of Sewers.....	7,022

From this it appears that the Sewer Bureau built and supervised the construction of less than one-half the total mileage constructed during this year.

Unsewered Streets. Mr. Loomis, Chief Engineer of the Bureau of Sewers, estimates that at the end of 1909 there were 23 miles of unsewered streets in the borough, many of these being single blocks in built-up territory.

Effect of Subway Construction on Sewer System. Until the commencement of the construction of the rapid transit subways no particularly difficult problems had arisen with regard to the alignment and grades of the sewers of Manhattan, but as nearly all the principal sewers lie in streets which cross the subway streets at right angles many

serious interferences have since been encountered. There is now a prospect of additional subways north and south on First, Second, Third, Fourth, Fifth, Sixth, Seventh, Eighth, Ninth and Eleventh avenues, as well as on Broadway and West Broadway, and of crosstown subways on Canal, Fourteenth, Thirty-fourth and Forty-second streets. Parts of some of these lines have now been built and parts of others are under construction. The borough is thus facing the necessity of reconstructing the entire sewer system as possibly a cheaper and better plan than the remodeling of each sewer when interfered with. The latter plan involves the probable employment of inverted siphons for the large storm water sewers.

As it would be impossible to provide overflows or reliefs for inverted siphons in many of these locations, restrictions of the cross sections by deposits occurring in the low-level, horizontal portions during dry weather would tend to cause inundations and flooding by back water. Such structures could be cleaned out only with difficulty unless special large submerged pumps, for emergency use, were installed and kept ready for service at each siphon.

Another serious complication due to subway construction arises from the fact that many of the streets are so narrow that in building the subways the sewers have been crowded off to one side into spaces too small to permit of their proper care and repair; in some places they have been crowded entirely off of the streets upon private property.

In all the sewer reconstruction work which has been undertaken so far, as a result of subway construction, the object has been simply to restore the existing sewers without regard to the future requirements of districts which now have no sewers.

Changes in System Suggested to Facilitate Street Washing. Still another complication is gradually coming to the front due to the modern tendency towards washing the streets with water and flushing into the sewers the street dirt and detritus not removed by the Street Cleaning Department, thus gradually filling up the lower comparatively flat sewers near the outfall at the river front, as well as the sewers whose grades have been flattened by reason of the construction of the subways. To adapt the sewers to the purposes of street flushing, the gradients should be as steep as practicable, and catch basins should be omitted. This in turn would require the separation of the house sewage from the water reaching the sewers from the streets and roofs of houses, for the reason that the house sewage must necessarily be collected at a great enough depth to drain basements and cellars, while the storm water drains should be placed as high as the requirements of traffic on the streets will permit in order to take advantage of all the slope available.

Desirability of Reconstruction of Some of the Sewers on the Separate Plan. The reconstruction of Manhattan's sewers would involve great expense and inconvenience, and yet in the long run, if the projected lines of subways should be built, it would be cheaper to rebuild the entire sewerage system on the separate plan, where interfered with by the subways, than to try to remodel the connections and restore the existing system as a repair job. Their reconstruction would necessitate reconnecting all the buildings to the new sanitary sewers and installing in each building pipes to convey the roof water to the new storm water drains.

Possibly the lowering of some of the future subways at critical points would avoid the need for the reconstruction of some of the sewers.

Public Service Commission and the Sewers. A more effective co-operation should be established between the Bureau of Sewers and the Public Service Corporation. The Bureau of Sewers is frequently embarrassed by the authority conferred by Act of Legislature on the Public Service Commission under which it has the right to remove out of the way all sewers and other conduits interfering with subway construction, subject only to the "reasonable requirements" of the Borough President. Under such conditions, it being impossible for the Public Service Commission to plan for the future sewerage of the whole borough, much money is wasted in alterations, removals and the rebuilding of sewers without reference to a general plan or policy. Chief Engineer Loomis, recognizing the necessity of reform in this direction has repeatedly recommended that an exhaustive investigation be undertaken to establish a policy with respect to future sewerage that shall be conformable to the requirements of the rapid development of this great metropolitan area.

Under existing conditions the Public Service Commission assumes that it has the right to design and execute the necessary changes in the sewerage system. In several instances changes of considerable extent have been completed before official notification of their necessity has been given the Bureau of Sewers.

The largest sewer under construction in the city at the present time (1909), the Duane street outlet, is being built by the Public Service Commission in connection with the Williamsburg loop subway. The Chief Engineer of the Bureau of Sewers states in his annual report for the year 1909 that the Commission "ignores the city authorities, claiming the right to do such work without supervision."

The reconstruction of the sewerage of the lower part of the city upon the separate system has been advocated by the Bureau of Sewers, using deep pipe sewers for house sewerage and shallow sewers for storm water removal, to reduce stoppages,

facilitate inspections, save in maintenance charges and simplify the problems connected with subway construction.

Recommendation. In view of all the circumstances the Metropolitan Sewerage Commission recommends that a detailed study be undertaken, in co-operation with the Bureau of Sewers and the Public Service Commission to devise a comprehensive scheme for the rebuilding of Manhattan's sewerage system, laying out the new plan so as to utilize the existing sewers to as great an extent as possible. The new storm water sewers should be located near the surface of the streets and the sewers for house drainage should pass beneath the subways, or over them, as circumstances warrant.

House sewage should be intercepted for conveyance to suitable points for screening, or subsidence, or both, as necessary in each case, or for crude discharge. Proper methods of discharge should be devised for all localities whether the entire system be rebuilt or not.

In connection with the storm water sewers it may be advantageous to construct the storm water inlets without catch basins so as to permit the washings from the street surfaces, as well as the snow in winter, to be carried away by the sewers.

MAINTENANCE OF THE SEWERAGE SYSTEM

The entire sewer maintenance force in Manhattan comprises but 60 carts and from 200 to about 300 men and consequently the 522 miles of sewers and 6,300 catch basins in the system are seldom examined, except during the routine work of cleaning, until trouble is reported.

The sewers are not flushed. Being generally of ample size for their respective drainage areas, it is the practice to let deposits accumulate to a depth of from 10 to 20 inches, whence they are removed through the nearest manhole by hand labor. Cleaning the sewers by contract has been tried several times, but has not been found satisfactory.

Cleaning Basins. During 1909, 14,381 basins were cleaned, and 5,886 examined, so that each one of the 6,348 should, on the average, have been cleaned every 5.3 months, and examined every 13 months.

Cleaning Sewers. The percentage of total mileage of the sewers cleaned and the costs of cleaning, per foot, since 1885, are given in Table III.



STRUCTURES BENEATH THE STREETS OF NEW YORK

In addition to sewers the structures beneath the streets of New York include:

Drinking water supply pipes
Salt water fire service pipes,
Gas pipes, Steam pipes,
Electric light conduits, Electric power conduits,
Telephone conduits, Telegraph conduits,
Pneumatic mail tubes, Subway railroads.

TABLE III

COST OF CLEANING SEWERS IN MANHATTAN

Year	Per cent. of total mileage of sewers cleaned	Costs per foot to clean
1885.....	....	\$0.0054
1886.....	2.6	.39
1887.....	3.6	.23
1888.....	4.5	.26
1889.....	7.0	.19
1890.....	10.4	.15
1891.....	5.7	.13
1892.....	3.3	.14
1893.....	3.9	.142
1894.....	3.2	.121
1895.....	2.6	.118
1896.....	7.7	.148
1897.....	9.8	.134
1898.....	9.1	.122
1899.....	9.1	.296
1900.....	11.5	.185
1901.....	13.3	.185
1902.....	17.1	.130
1903.....	24.7	.090
1904.....	26.0	.090
1905.....	19.5	.126
1906.....	28.2	.097
1907.....	39.8	.095
1908.....	41.9	.084
1909.....	47.5	.069

A very substantial reduction in cost per foot for cleaning is to be noted. Nearly half the total mileage of sewers was cleaned during 1909, but this is only relative, as no doubt some sewers are rarely, if ever, cleaned, while others are cleaned many times per year. It is interesting to note that in the last 10 years the percentage of sewers cleaned has increased from about 10 per cent. to nearly 50 per cent.

The street cleaning and sewer maintenance bureaus being entirely separate and distinct, considerable additional expense is thrown upon the Bureau of Sewers by the

pushing and washing of street dirt into the catch basins by the street cleaners. The expense of removing the dirt from the 6,300 catch basins is manifestly much greater than would be the cost of removing it from the street surfaces by the street cleaners. If, however, there were no catch basins, and if the sewers were laid on self-cleansing gradients, it would be possible to flush the street dirt, including a large part of the snow, into the sewers.

If catch basins were to be done away with entirely, grit or deposit chambers and mechanically cleaned screens would be desirable at each sewer outlet.

Condition of Sewers. Many of the old sewers are still in good condition, although most of those built with lime mortar, are, from disappearance of the mortar, so badly distorted by settlement as to render inspections dangerous or impossible.

Ordinance Against Steam, Acids, etc.—In some cases steam, very hot liquors and acids have disintegrated the mortar joints to such an extent as to cause the longitudinal splitting of the sewer and the lowering of its crown.

The discharge of steam and other objectionable things into the sewers is prohibited under the provisions of the City ordinances.

The ordinances relating to the discharge of steam, fats, iron or stone refuse, and chemicals into the sewers are as follows:

CHAPTER 6, ARTICLE 9, SECTION 174, REVISED ORDINANCE OF 1880

No connection with or opening into any sewer or drain shall be used for the conveyance or discharge into said sewer or drain, of steam from any steam boiler or engine, or from any manufactory or building in which steam is either used or generated, under the penalty of \$50 for each and every day during any part of which such connection or opening may have been used for that purpose. This penalty shall be imposed upon and recovered from the owner and occupants severally and respectively, of such manufactory or building.

Sec. 163. And any manufacturer, brewer, distiller or the like, permitting any substance to flow into any sewer, drain or receiving basin, which shall form a deposit that tends to fill said sewer, drain or basin, shall be subject to a penalty of \$50 for each offence.

Sec. 165. No butcher's offal or garbage, dead animals or substance of any kind whatsoever shall be placed therein or deposited in any receiving basin or sewer; and any person so offending or causing any such obstruction or substance to be placed so as to be carried into such basin or sewer shall be subject to a penalty of \$10 for each offense; any person injuring, breaking or removing any portion of any receiving basin, covering, flag, manhole, vent or any part of any sewer or drain, or obstructing the mouth of any sewer or drain shall be subject to a penalty of \$20 for each offense. Nor shall any quantity of marble, or other stone, iron, lead, timber or any other substance exceeding one ton in weight, be placed or deposited upon any wharf or bulkhead through which any sewer or drain may run.

Sec. 167. It shall be the duty of every person having charge of the sweeping and cleaning of the streets in the several wards, to see that the gutters are properly scraped out before the water is suffered to flow from any hydrant for the purpose of washing the same, in order that no substance or obstruction be carried into any of the receiving basins. Every person violating this section shall be subject to a penalty of \$5 for each offense.

To secure a conviction, under the section relating to discharging steam into the sewer, however, the courts require that steam found issuing into a street sewer from a connection be traced back to its source, in some way leaving no doubt as to whence it came. This, in many cases, is impossible. The difficulties are increased by the fact that the Bureau of Sewers has no right of entry in the private properties connected with the sewers and hence can not send in mechanics and steam fitters to examine the pipe connections and trace the discharges from hot pipes.

In several instances steam has entirely disintegrated the mortar joints of the sewers. Further, it frequently boils the sewage, thus causing the evolution of foul odors at manholes and making ingress to the sewer for inspections impossible.

The compulsory introduction of condensers or steam traps on the house connections of all buildings where steam or hot water is used, or the extensions of exhaust pipes to the tops of the buildings, coupled with the right, to the Bureau of Sewers, to enter private properties for purposes of inspection, together with the right to correct the evils at the expense of the offending parties, on their failure to make the necessary changes after due notice, would put an end to the violation of the terms of the present unenforcable ordinance.

Reconstruction. In the 1909 annual report of the Chief Engineer it is stated that about 55 miles of sewers in Manhattan are much out of repair, cost large sums to keep in order and are liable to frequent stoppages, resulting some times in great damage to adjacent property. Most of these sewers were laid in 1868 to 1873.

Some 24 different sewers are specifically mentioned as being in need of repairs or of reconstruction. Of these, three outlet sewers at the following points are mentioned :

1. At Albany street and Hudson river.
2. At foot of Seventy-ninth street, East river.
3. In Market street.

Troubles and Complaints. Most of the complaints against the sewerage work arise from flooded cellars due to back water caused by stoppages in the sewers, and floods from the streets due to the occurrence of extremely heavy rains at times when the sewers may have become partly choked with deposits. Considerable sums of money are collected from the City, annually, for damages from back water and flooding, under a court decision to the effect that unless the sewer in question had been inspected and left clean

and in good repair within the previous six months, the City was liable for the damages shown.

Difficulties of this nature are most common in the portion of the city served by old sewers along the low lying streets near the water-front, where, from the tide-locking of the sewers and the flat slopes caused in many instances by the settlement of the sewer, deposits accumulate to considerable depths.

DISPOSAL OF THE SEWAGE

Discharge Into Harbor. All the sewers of Manhattan discharge into the tidal water surrounding the Borough. The discharge usually takes place at the pier-head line, although some of the sewers discharge at the bulkhead line. No attempt is made to purify the sewage. The storm water from the street surfaces receives a very insignificant amount of coarse screening and subsidence in passing into and through the catch basins at street corners, but otherwise everything that enters the sewers is free to pass out into the harbor waters unless deposited in the sewers in places where the velocities are too slight to keep the bottom scoured clean.

Sewage Deposits Along Water-front. In spite of the catch basins at present in use, large quantities of solid materials are discharged into the harbor from the sewers, and these deposits, and those occurring as the result of scour by the tidal currents, and freshets on the water-sheds of the stream tributary to the harbor, require the continuous dredging of mud from the bottoms of the slips and docks along the river frontage of Manhattan. The quantities of mud dredged by the Department of Docks during the years 1903 to 1907, inclusive, from the slips and along the shore line of Manhattan, exclusive of the dredging done on the Brooklyn and Staten Island shores or of that done by private parties or in connection with new construction works, are shown in Table IV.

TABLE IV
CUBIC YARDS OF MUD DREDGED BY THE DOCK DEPARTMENT ALONG THE SHORES OF
MANHATTAN ISLAND

Year	From the North River	From the East River	From the Harlem River
1903	377,765	129,502	11,187
1904	291,320	88,263	32,490
1905	214,566	159,601	37,255
1906	244,967	144,418	18,328
1907	189,643	117,957	35,375

Nuisances. The increasing discharges of sewage into the harbor at the pierhead line, unless improved methods of disposal are put in force, will in time bring about an unbearable condition. Even at the present time local nuisances exist along practically the entire water-front. The situation is complicated by the movement of the water in the various rivers under tidal influences, and by the tendency of the sewage, which is usually warmer and of less specific gravity than the harbor waters, to spread out upon the surface instead of becoming immediately mixed therewith. On the numerous trips of inspection made by members of the Metropolitan Sewerage Commission fragments of human feces have been seen in the water at practically every point from the Battery to Spuyten Duyvil creek in the Hudson, East and Harlem rivers, and at all stages of tide. Further than this, distinct nuisances exist at many points.

In the majority of cases the tops of the outlet sewers at the pierhead lines are about at the level of mean high tide, though some are lower. In the larger sewers such as that discharging at Oliver street, East Forty-ninth street, East One Hundred and Tenth street, and Canal street, the rising tide backs water into the sewers to great distances, frequently preventing the discharge of the sewage until nearly time for the tide to turn. In some of these tide-locked sewers deposits form rapidly and their removal by hand is a laborious and expensive process.

Particularly offensive conditions exist at Piers 25, 31, 32, 40, 51, 54, 59 and 61, at Twenty-third street and Thirty-eighth street along the North river; at Oliver street, East Forty-ninth street, East One Hundred and Tenth street, and the East river from Hell Gate to the Harlem river, as well as the Harlem river for the greater part of its length.

Crowding of Sewage Shoreward by Currents. It is commonly observed that during the prevalence of flood currents the discharges from the sewers are driven back into the slips and under the wharves instead of being carried out into mid-stream and lost by dispersion and dilution. During these periods when enormous quantities of clean sea water are entering the harbor through the Narrows, and from Long Island Sound, the concentration of sewage along the shore line and in slips and docks is greatest. On ebb currents the sewage that has not been dispersed passes out into the rivers and is more or less mixed with the land water on the surface of the outgoing sea water as well as with the sea water itself, but the grease, excreta and other floating matters that adhere to the piles, dock walls, piers, and harbor bottom exposed at low tide, slowly putrefy and give off offensive odors.

Practically all of the mud deposits removed from the slips and docks along the Manhattan shores, averaging annually over 250,000 cubic yards along the Hudson river front, 130,000 cubic yards from the East river and 27,000 cubic yards from the

Harlem, have their origin in the discharges from the sewers, the deposits taking place as the velocities of the flood currents decrease.

Various chemical and bacteriological tests, and tests made with floats, as well as with dyed sewage, confirm the general statements as to the tide-locking of the sewers, the forcing of sewage back into the slips on flood currents, the holding of sewage for hours in docks and unused slips and the very unsatisfactory condition as to dilution and dispersion that obtains along the whole water front.

Effect on Public Bathing Establishments. The location of public bathing establishments at places where the discharges from the sewers can pass through them, the surrounding of recreation piers with sewage, the fouling of the docks and slips where ocean, sound and river steamers berth and receive passengers, the location of market places in neighborhoods when food stuffs may become infected by flies, rats, insects and vermin that hunt their food along the polluted water fronts should not be tolerated.

Future Conditions. It is impossible to predict with accuracy to what limits the population of Manhattan or the ultimate quantity of sewage from Manhattan may reach in the distant future. In certain wards the population is already considered to be greater per acre than on any other equal area in the world.

Whether the multiplication and improvement of rapid transit facilities and the opening of suburban territory to cheap homes accessible for one fare will retard further excessive congestion, whether the constant advance of business into the uptown districts will increase or decrease the resident population in this district, are questions which do not permit of precise answers. That the day population in this district will continue to increase for many years there can be no doubt; it is equally certain that the character of the resident population will change as business houses and office buildings advance uptown. It is probable that the quantity of sewage discharged into the harbor from this district will increase as these changes take place, and about in proportion to the changes in population unless measures are taken to prevent it.

So far as the capacity of existing sewers to receive house sewage is concerned this question is not of importance for the reason that, being built large enough to dispose of the storm water from the streets and roofs of buildings, their capacity is ten to twenty times greater than would be required for sewage alone, so that no complications are likely to result until the population has increased to many times its present figures.

So far as the effect on the quality of the harbor waters is concerned, however, the question is one of great importance. With increasing population will come increas-

ing pollution without a corresponding increase in the quantity of tidal water for digesting and dispersing the sewage. The inevitable result, unless intelligent oversight and revision are given to the future sewerage plans of the district, will be the aggravation of local and the creation of general nuisances.

BOROUGH OF BROOKLYN

GENERAL FEATURES AND CONDITIONS

Principal Topographical Characteristics. The Borough of Brooklyn lies on the western end of Long Island. Its built-up territory is the largest in area, by far, of the boroughs of The City of New York, although it is second in population to Manhattan. Brooklyn has grown into a large city by the gradual amalgamation of several separate towns, including Brooklyn, Flatbush, Parkville, Blythebourne, New Utrecht, New Lots, Gravesend, Williamsburg, Bushwick, East New York, Sheepshead Bay, Bay Ridge, Fort Hamilton, Bensonhurst, Bath Beach, Flatlands, Coney Island, Bergen Beach and Canarsie, and the subsequent obliteration of the boundary lines between these separate towns by the building up of the intervening territory.

This borough has an area of 57 square miles and a total water frontage on the East river, Upper bay, Narrows, Gravesend bay, Sheepshead bay, Atlantic ocean and Jamaica bay of upwards of 30 miles.

Unlike Manhattan, there are no rock outcroppings in Brooklyn, the end of Long Island being the southern terminus of the great terminal moraine. The borough, therefore, lies upon a gravel formation interspersed with strata of sand, clay and alluvium, and containing sometimes boulders of considerable size.

The main topographical feature of the borough is the ridge of the moraine, which rises to a height of about 200 feet above sea level at several points within the borough, and follows a nearly straight line from Fort Hamilton through Bay Ridge, Greenwood Cemetery, Prospect Park and Ridgewood in Brooklyn, and Forest Park and Richmond Hill in Queens, passing about one-half mile to the north of Jamaica. The edge of the crest of this ridge, which drops off very steeply on its southerly face, divides the borough into two nearly equal parts, the southerly of which drains to Jamaica, Sheepshead and Gravesend bays on the Atlantic side, and the northerly to the Narrows, Upper bay, East river and Newtown creek. A typical north and south section through Brooklyn, drawn from Brighton Beach to the mouth of Newtown creek, would show a gradual rise from the ocean, at an average rate of about 10 feet per mile to the foot of the south slope of the terminal moraine, near Prospect Park, a distance of 6 miles; then in less than half a mile, a rise of some 80 feet, followed by

a rather gradual descent towards the north to sea level again at the mouth of Newtown creek, a distance of 5 miles. All the land lying southeast of the foot of the south face of the moraine crest is of the same general character as to slope, being very flat and broken only by slight rolling variations in the surface. At the extreme eastern end of the borough the distance from the foot of the slope to tide water is less than two miles. In this great flat plain there are few well defined drainage districts and problems of much difficulty have arisen in providing adequate sewerage facilities. The main division of the territory for sewerage purposes may be described as follows:

The East New York district is drained to a sewage purification plant lying at the southerly edge of the town, about half way between its east and west lines, the effluent being discharged into a tributary of Jamaica bay.

In Canarsie a few sewers discharge into nearby waters. The Flatbush district drains to Paerdegat basin, about half-way between Flatlands and Canarsie. A large sewer has recently been completed to take the sewage of a large part of Flatbush to an outlet into the Upper bay at Sixty-fourth street.

The sewage of Sheepshead Bay and vicinity is taken to a sewage disposal plant on Shellbank creek, at the east end of the district.

Coney Island and Brighton Beach also drain to sewage disposal plants back of each district and discharging into Coney Island creek.

The sewage of Bath Beach, Ulmer Park and Bensonhurst, except a small district in the eastern part of Bensonhurst, is intercepted for the most part and discharged into the Narrows at the Ninety-second street outlet. There are two or three outlets, from this district, however, which discharge into Gravesend bay.

With the exception of a few sewers discharging into Gowanus canal, including the large Greene avenue relief sewer, the balance of the Brooklyn area drains naturally to the Narrows, Upper bay, East river and Newtown creek with relatively steep slopes.

Owing to the small sizes of the older sewers much trouble has been had in the last-mentioned districts owing to their gradual change from suburban to urban settlements. To ameliorate conditions many large and expensive relief sewers have been built, to be followed later in some cases by the building of additional intercepting storm water sewers to relieve the already overburdened relief sewers.

Distribution of Population. The population of Brooklyn in 1905 was 1,355,100. The older section of the city which drains towards Buttermilk channel, East river and Wallabout bay, is quite densely populated, but the remainder of the area, although housing a very large population, partakes more of the nature of groups of suburban villages separated in some cases by extensive areas of undeveloped lands.



The East River Looking Northeast from near the Battery. The bottoms of the slips for docking vessels are covered with deposits of sewage sludge



The East River near Hell Gate Showing a Sewer Discharging from Manhattan. Many sewer outlets are at the bulkhead line as in this case

Some of the difficulties that face the Bureau of Sewers in the not distant future may be appreciated from the topographical features of the southerly half of the borough, where an area of some thirty square miles lies in a plain with an average inclination towards tidewater of not over about two feet in a thousand, and having at places areas of considerable extent lower than the surrounding lands.

General Conditions. The following description of the general conditions surrounding the sewerage of the borough is quoted from the 1907 annual report of Mr. E. J. Fort, Chief Engineer of the Bureau.

“The topography of the borough is such that, in order to provide proper drainage for the whole area, it must be divided into numerous drainage districts, each one of which, in nearly all cases, has its own separate and independent outlet. Each drainage district, therefore, contains an independent and complete system of sewers. Tide water can be reached on three sides of the borough. The older portion of the borough, where the sewer systems are nearly completely built and have been so in most cases for some years is divided into thirty-nine drainage districts. Drainage plans have never been designed for some of the low lying land along the shores of the East river and Newtown creek. At least two more drainage districts will be added to the above number when plans now under way for these lands are completed. The territory is to be improved in the near future and there is immediate need for drainage plans. These plans are now far advanced and will be completed during the coming summer. For the district along Newtown creek a ‘separate system’ of sewers will be necessary, because of the slight elevation of legal grades above tidewater and because the discharge of house sewage into Newtown creek is prohibited by law. It will be necessary to pump the house sewage into existing sewers.

“The suburban portions of the borough, where by far the greater part of the sewers are not yet built, has been only partially provided with drainage plans. Sewers have never been designed for the low land along nearly the whole southern boundary of the borough, extending in places some distance inland and comprising an area of several thousand acres. The design of sewers for this territory is more difficult than for any other portion of the borough, and is proceeding rather slowly on that account.

“The suburban area, for which sewers were designed some years ago, was divided into eleven drainage districts, in a number of which no sewers have been built, and in some of which only the outlets have been built. Where outlet sewers have not been built the drainage plan will be, or has been, entirely redesigned, and in nearly all cases a ‘separate system’ of sewerage provided. To do this work thoroughly well is a large undertaking. It should be understood that some of these drainage districts are of sufficient extent to support, and will in the near future support, a population of several

hundred thousand people. The drainage system is as extensive and its design (outside of the problem of the proper disposal of the sewage) much more difficult than that of the average city of equal population. A population of 100 people per acre, for which the sewers are calculated, represents a purely residential development, about such as can be found in parts of the Twenty-third and Twenty-sixth Wards, and is as dense a population as can reasonably be expected for years to come.

“Several pumping plants must be built within the next few years, or before outlets can be provided for large drainage areas. Requests will no doubt be made within the next year for the acquisition of small pieces of land upon which to locate these pumping plants. The first ones to be built should be those at Flatlands and Paerdegat avenues and at Avenue V and West Eleventh street. A number of auxiliary pumping plants will also be required to enable house sewage to be delivered at disposal works where surface elevations are so slight that sewers cannot otherwise be laid at self-cleansing grades. These auxiliary plants can be placed at street intersections entirely under the surface of the street, and it will be necessary to acquire no land upon which to locate them.

“I wish to call attention again to the necessity of outlets for storm sewers at tide water level at Avenue V between West Tenth and West Eleventh streets, and at various points along the line of the projected Gravesend Ship canal. Stryker basin, Stillwell basin and Gravesend basin, as at present shown on the map of the city, may be dispensed with as storm water outlets, but Gravesend basin should be replaced by a drainage canal, between West Tenth street and West Eleventh street, and extending between Avenue V and the Gravesend Ship canal. The Gravesend Ship canal itself, or at least a large portion of it, is also necessary for this purpose, and title to the property necessary should be acquired in advance of the construction of outlet sewers. The property required will undoubtedly increase in value hereafter, and there is every reason for proceeding with the matter now.

“The old sewers in the developed portion of the borough, as well as those still to be designed or built in suburbs, will continue to present hydraulic and sanitary problems for solution for some years to come. As the system increases in extent and complexity and methods of sewage disposal are changed, and as new pumping stations are placed in operation, the maintenance of the system will become a more difficult and expensive undertaking, and will require more skill and care to produce satisfactory results.”

Bureau of Sewers. The Brooklyn Bureau of Sewers, one of the departments under the Borough President, is administered by a Superintendent of Sewers. The Bureau has two distinct and separate divisions, a maintenance department and an engineer-

ing department, under the direction of the Chief Engineer. With the exception of the Superintendent of Maintenance all the employees are civil service men.

The Maintenance Department has charge of inspection of connections, basins and small sewers (24-inch and under), of cleaning basins, manholes and sewers, of repairing basins, manholes and small sewers and of the disposal plants.

The Chief Engineer has charge of the design, construction and inspection of new work, and to act in an advisory capacity to the Maintenance Department in important matters. The work of these two departments is so adjusted as to avoid mutual interference and at the same time place at the service of the Maintenance Department, if needed, the Engineering Department's knowledge and advice. Under the Chief Engineer the force is separated into five divisions, the principal ones being in charge of an Engineer of Design and an Engineer of Construction.

Prior to constructing sewers, the Bureau must receive proper authorization from the Board of Estimate and Apportionment. Sewers can be built, however, by a combination of private citizens, in which case the plans must be prepared and the work, during construction, must be inspected by the Bureau. In such cases a charge is made against the properties benefited, the amount being sufficient to cover the cost of the office and field expenses. Compliance with these rules relieves the properties from future sewer assessments. Responsibility for proper design and adequacy rests with the City after the bureau has approved and accepted privately built sewers.

SEWERAGE WORKS

Design. The earlier sewers of Brooklyn were designed to carry off very moderate rainfalls and, while perhaps satisfactory in a degree in those days, have proven sadly deficient in capacity as the streets in their districts have become covered with imperious pavements and the areas of roofs and paved courtyards have increased.

In 1880 the late Julius W. Adams wrote of this, in "Sewers and Drains for Populous Districts," that when in 1856 he was projecting the sewer system of Brooklyn the only rainfall records to be had of individual rainstorms were those of a Dr. Minor, of Brooklyn, covering only the years from 1849 to 1856; from these it appeared that an allowance of one inch of rainfall per hour running off from the district would be ample. He recognized that great rainfalls might be anticipated at long intervals, but reasoned that the resulting damage would be insignificant. He also refers, in commenting on these conditions, to the Report of the Engineer to the Commission of Drainage, Brooklyn, 1859, from which he quotes "No system of sewage yet proposed in any city contemplates the removal of *excessive* storm water by means of sewers alone,—such storms, for instance, as discharge for short intervals two inches or

three inches of rain in one hour. These occur at long intervals and are of short duration and the damage is usually confined to limited areas, whilst the construction of sewers to meet the contingency would be attended with an enormous expense over the whole city, both in construction and repairs, and prove of doubtful efficacy when suddenly called upon and extremely objectionable as conduits for the ordinary flow of sewage."

The old standards and methods remained in force in the department for many years, even so late as 1890, when the Greene avenue Relief Sewer was designed, then called "The Main Relief Sewer of Brooklyn." Its capacity was based on the removal of 1,313 cubic feet per second from an area of 1,325 acres, corresponding substantially to a rate of run-off of one inch of rainfall per hour.

Until the spring of 1907, the legal plans for the sewers in nearly all the outlying districts of the borough were prepared by using the invert grade or slopes of the bottoms of the sewers for calculating capacities instead of the hydraulic grades or slopes of the water surface in the sewers.

The result of this mistaken policy was to produce sewers that would overflow at manholes and be, so to speak, drowned out whenever the flow approximated the maximum capacity. These plans are now being revised and adapted to modern requirements while utilizing to as great extent as practicable the works and outfalls already existing in such districts.

The sewers in Brooklyn are now designed on the basis of a schedule prepared under the direction of E. J. Fort, the present Chief Engineer. In the 1906 report of the Bureau of Sewers a full history of the old methods is given, together with reasons for adopting present formulas and methods. The detail work of design is done under the direction of Mr. G. T. Hammond, Engineer of Design. The following is an abstract of the rules laid down for future designs:

1. Sewers taking house sewage only are to be called sanitary sewers and those taking rainfall, storm sewers or drains.
2. The combined system is to be used wherever practicable.
 - a) The combined system is to be used on upper and high portions of districts.
 - b) The limit is the lowest point where storm water overflows can be used. Below this point the storm water sewers are to run at higher level than house sewers, so as to get free outlet to tide water.
 - c) The house sewage is to be pumped from lower levels to points of disposal.
3. Storm water is to be excluded from sanitary sewers in all combined systems by designing overflows unless necessary to pump the storm flow.

4. Disposal works shall be provided for areas draining naturally into Jamaica bay, Sheepshead bay and Coney Island creek.

5. The quantity of flow is to be provided for on the following assumptions:

a) A population of not less than 100 per acre is to be provided for; more if conditions warrant it on investigation.

b) 100 gallons of sewage per capita is assumed to reach the sewers in 16 hours.

c) Sizes and flows:

8-inch to 18-inch sewers are to run one-half full.

18-inch to continue in line of sewers till 0.7 full.

All larger sewers to run 0.7 full.

6. Hydraulic gradient:

a) All sewers are to be designed on hydraulic gradient.

b) A sewer may change in size and shape, but shall still preserve the hydraulic grade line and it shall lie within the sewer.

c) Changes of shape are to be made by dropping invert or widening.

7. Formula for flow:

Kutters $n=.013$ for pipe sewers.

$n=.015$ for brick and concrete sewers.

8. Quantities of storm flow to be determined by McMath's formula for run-off in conjunction with rainfall records and rainfall intensity curve from the automatic rainfall gauge in Water Department.

The sewers are assumed to run full, and to be egg-shaped when possible.

The Sewers. The sewers in Brooklyn are of many types, sizes and conditions as to age and state of repair. Among the older sewers are many stone drains whose courses are not known, as well as many cement, vitrified pipe, brick and concrete sewers and drains.

As a rule the sewers are built on the combined plan; that is, to carry both house sewage and storm water. They discharge into the nearby tidal waters, or lead to a purification plant, whence the effluent is discharged into tide water.

The sewers are generally circular in shape, and, for sizes above 24 inches diameter, of brick or concrete. Vitrified clay and cement pipe sewers have been extensively used for the smaller sizes.

The sizes and courses of the Brooklyn sewers are shown on a map of the borough, published with the 1907 Annual Report of the Bureau of Sewers.

The sewers have, in many districts, proven too small, having been designed on incomplete data, and such extensive street and cellar floodings have resulted therefrom that a comprehensive system of relief sewers has been planned and partly constructed for relieving the flooded districts, as hereinafter described.

Catch Basins. Catch basins are provided at street corners to intercept and retain the heavier particles carried into the sewers from the street surfaces. It has not been considered feasible to omit the basins owing to the flat grades of many of the sewers, which act much as sewers of deposit when the flow through the sewer is not rapid. The Bureau considers that the cost of removing deposits from the catch basins is less than the cost of removing them from the sewers would be.

Ventilation. Manholes, with perforated covers, are built at frequent intervals along the sewers, and ventilation takes place in the sewers by the ingress and egress of air, from the street, owing to the varying volume of flow and relative differences of temperature between the sewer air and the outer air.

House Connections. House connections are made in unpaved streets in conjunction with contracts for sewers. The connections are usually put at intervals of 20 feet on each side of the street and lead to a point 2 feet back of the curb line where, if the elevation of the street surface will permit, they are laid 9.5 feet deep.

Outfalls. The sewers discharging into tide water are in recent plans arranged with the elevation of the outlet high enough to avoid tide-locking. The older outfalls are in most cases placed so low that high tides completely submerge them.

Nearly all the older sewers discharge at the bulkhead line in the docks and slips; the newer ones, especially the modern district relief sewers, are extended out to the pierhead line. A few of the older sewers, the Fulton street sewer, for instance, have been extended to the pierhead line to ameliorate the nuisance resulting from discharging into the boat slips, but improvements in this matter are still greatly needed.

The troubles arising from the tide-locking of the outlets of the sewers have been experienced and recognized for a generation, and yet until recently little effort has been made to better these conditions. Evidence of the appreciation of these evils years ago is found in the following comment: "From a mistaken view of the purpose to be secured by a proper system of drainage, the tendency appears to be constantly towards placing the outlets of the sewers at too low a level, and the only defect in the system of sewers in the city of Brooklyn grows out of the mistaken effort to drain below tide level, and the consequent sealing of the outlets of some of the sewers by the high tides which usually accompany severe storms." (Julius W. Adams, *Sewers and Drains for Populous Districts*, 1880.)

The outlets of the Brooklyn sewers are given in Table V.

TABLE V

OUTLETS OF BROOKLYN SEWERS

<i>Into Newtown Creek.</i>	DIAMETER.	
Scott avenue; Brooklyn-Queens Interborough Sewer	15 ft.	0 in.
Oakland avenue	3 ft.	0 in.
Pink street	1 ft.	6 in.
<i>Into the East River, between Newtown Creek and Wallabout Channel.</i>		
Freeman street	2 ft.	6 in.
Green street	2 ft.	0 in.
Huron street	7 ft.	0 in.
Greenpoint avenue	2 ft.	0 in.
Quay street	5 ft.	6 in.
North Twelfth street.....	6 ft.	6 in.
North Fifth street.....	2 ft.	6 in.
Metropolitan avenue	5 ft.	0 in.
Grand avenue	2 ft.	0 in.
South Fifth street.....	12 ft.	0 in.
Broadway	4 ft.	0 in.
<i>Into Wallabout Channel.</i>		
Kent avenue	9 ft.	0 in.
Wallabout place	3 ft.	6 in.
Clinton avenue	4 ft.	0 in.
Carlton avenue (through Navy Yard)	5 ft.	0 in.
Raymond street (through Navy Yard)	5 ft.	10 in.
Navy street (through Navy Yard).....	6 ft.	0 in.
<i>Into East River between Wallabout Channel and Buttermilk Channel.</i>		
Hudson street	1 ft.	3 in.
Hudson street	6 ft.	0 in.
Hudson street	1 ft.	3 in.
Gold street	1 ft.	6 in.
Gold street relief sewer.....	14 ft.	0 in.
Bridge street	1 ft.	6 in.
Pearl street	1 ft.	8 in.
Washington street	3 ft.	0 in.
Main street	3 ft.	0 in.
Fulton street	6 ft.	0 in.
Pierrepont street	2 ft.	0 in.
Remsen street	2 ft.	0 in.
Joralemon street	1 ft.	6 in.
Atlantic avenue	3 ft.	0 in.
Amity street	1 ft.	0 in.
Congress street	1 ft.	0 in.
Warren street (Old sewer).....	—	—
Harrison street	4 ft.	6 in.

TABLE V—*Continued*

<i>Into Buttermilk Channel.</i>	DIAMETER.	
Degraw street	1 ft.	6 in.
Degraw street (Gowanus canal flushing tunnel)	12 ft.	0 in.
Hamilton avenue (Old sewer)	—	—
Sullivan street	1 ft.	3 in.
Wolcott street	6 ft.	0 in.
<i>Into Atlantic Basin.</i>		
Bonne street	2 ft.	0 in.
Commerce street	2 ft.	0 in.
Verona street	2 ft.	0 in.
William street	2 ft.	0 in.
Clinton street	2 ft.	0 in.
<i>Into Gowanus Canal.</i>		
Butler street (Greene avenue relief)	15 ft.	0 in.
Douglass street (Storm)	3 ft.	6 in.
Degraw street (Storm)	2 ft.	6 in.
Sackett street	1 ft.	6 in.
President street	1 ft.	6 in.
Carroll street	3 ft.	6 in.
Carroll street (Relief)	4 ft.	0 in.
Second avenue (Storm)	6 ft.	6 in.
Nineteenth street	3 ft.	0 in.
Hamilton avenue	1 ft.	0 in.
Hicks street slip	3 ft.	6 in.
<i>Into Erie Basin.</i>		
Van Brunt street	2 ft.	6 in.
<i>Into the Upper Bay.</i>		
Forty-third street (Storm sewer)	5 ft.	0 in.
Forty-ninth street (Park Slope outlet)	10 ft.	0 in.
Sixty-fourth street (Flatbush outlet)	15 ft.	0 in.
<i>Into the Narrows.</i>		
Seventy-first street (Bay Ridge)	4 ft.	0 in.
Seventy-second street (Bay Ridge)	6 ft.	0 in.
Eighty-third street	2 ft.	6 in.
Ninety-second street (Dyker Heights outlet)	11 ft.	0 in.
<i>Into Gravesend Bay.</i>		
Fifteenth avenue	2 ft.	6 in.
Twenty-second avenue	2 ft.	6 in.
<i>Into Tidal Estuary at Benson Avenue.</i>		
And Twenty-fifth avenue, 4 sewers	1 ft.	6 in.
	1 ft.	6 in.
	2 ft.	0 in.
	1 ft.	0 in.



The Metropolitan District Showing Densely Populated Areas in Brown, Principal Sewers in Red and Large Trunk Sewers which are Building or Proposed in Broken Red

TABLE V—*Continued*

	DIAMETER.
<i>Into Coney Island Creek.</i>	
Outlet from Coney Island Disposal Plant	2 ft. 6 in.
Outlet from Brighton Beach Disposal Plant	2 ft. 0 in.
<i>Into Shellbank Creek.</i>	
Outlet from Sheepshead Bay Disposal Plant	2 ft. 0 in.
<i>Into Jamaica Bay.</i>	
Flatbush avenue	4 ft. 0 in.
Outlet from Disposal Plant at Van Sicklen and Hendrix avenues...	15 ft. 0 in.
<i>Into Paerdegat Creek and Basin.</i>	
Thirty-seventh street	6 ft. 0 in.
East Seventy-fourth street and Avenue J.....	3 ft. 0 in.
Outlet from Screening Plant at Flatlands and Paerdegat avenues...	10 ft. 0 in.
	7 ft. 6 in.

The positions of the larger of these outlets, as well as the courses of the main sewers leading thereto are shown on map facing page 248.

Growth of the System. The growth of Brooklyn's sewerage system since 1859, as shown by the number of house connections made, and since 1875 as shown by the number of miles of sewers built each year is shown in Table VI.

TABLE VI
GROWTH OF THE SEWER SYSTEM OF BROOKLYN

Year	House Con- nections Made	Total House Con- nections to Date	Miles of Sewers Built	Total Miles of Sewers to Date
1859.....	422	422	.....	.....
1860.....	1,695	2,117	.....	.....
1861.....	4,896	7,013	.....	.....
1862.....	3,168	10,181	.....	.....
1863.....	1,984	12,165	.....	.....
1864.....	1,301	13,466	.....	.....
1865.....	1,519	14,985	.....	.....
1866.....	3,605	18,590	.....	.....
1867.....	2,922	21,512	.....	.....
1868.....	3,286	24,798	.....	.....
1869.....	3,501	28,299	.....	.....
1870.....	2,972	31,271	.....	.....
1871.....	2,861	34,132	.....	.....
1872.....	2,845	36,977	.....	.....
1873.....	5,276	42,253	.....	.....
1874.....	3,648	45,901	.....	.....

DATA COLLECTED

TABLE VI—*Continued*

Year	House Connections Made	Total House Connections to Date	Miles of Sewers Built*	Total Miles of Sewers to Date*
1875.....	2,786	48,687	.....	290.72
1876.....	2,237	50,924	6.64	297.36
1877.....	2,110	53,034	3.49	300.85
1878.....	1,999	55,033	.62	301.47
1879.....	1,908	56,941	.17	301.64
1880.....	1,664	58,605	2.08	303.72
1881.....	1,872	60,477	2.31	306.03
1882.....	2,058	62,535	.76	306.79
1883.....	2,626	65,161	3.03	309.82
1884.....	3,079	68,240	5.47	315.29
1885.....	3,162	71,402	13.96	329.25
1886.....	3,093	74,495	14.23	343.48
1887.....	3,295	77,790	11.74	355.22
1888.....	3,302	81,092	16.91	372.13
1889.....	3,937	85,029	7.96	380.09
1890.....	3,168	88,195	10.84	390.93
1891.....	3,137	91,334	16.24	407.17
1892.....	3,068	94,402	21.32	428.49
1893.....	2,245	96,647	5.78	434.29
1894.....	2,174	98,821	24.86	459.13
1895.....	3,440	102,261	59.17	518.30
1896.....	3,696	105,957	18.60	536.90
			62.48**	599.38**
1897.....	3,300	109,257	11.09	610.47
1898.....	2,562	111,829	6.20	616.67
1899.....	2,608	114,437	16.63	633.30
1900.....	2,478	116,917	16.80	650.10
1901.....	2,244	119,159	14.76	664.86
1902.....	2,093	121,242	18.37	683.23
1903.....	2,444	123,686	20.02	703.30
1904.....	4,526	128,212	31.53	734.83
1905.....	5,888	134,100	31.67	766.50
1906.....	5,884	139,984	17.76	784.26
1907.....	5,238	145,222	19.06	803.32
1908.....	3,894	149,116	11.04	814.36
1909.....				

* Note—There may be some small errors due to the fact that the actual miles built and net miles added, i. e., miles built less miles abandoned, are not always clear; e. g., 0.05 mi. added in 1903.

** Wards 29, 30, 31 added.

Sewers and Subway Construction. In Brooklyn the construction of the Rapid Transit Subways has necessitated several important changes in sewers already constructed as well as in the plans for projected sewers. The storm relief sewers are designed to render the main relief sewer system adequate and to rearrange the mains so as to take them out of the way of proposed subway construction.

The Public Service Commission has authority to change the existing and to build new sewers, but before undertaking any changes notification must be given to the Bureau of Sewers, upon receipt of which an Inspector will be detailed to make an examination and report thereon. Changes can only be made with the approval of the Bureau, and under the inspection of the Bureau's representative.

No friction results from this arrangement, the co-operation being mutual and harmonious. Upon completion, the new or altered work is placed under the jurisdiction of the maintenance department of the Bureau of Sewers, prior to which time all complaints of inadequacy are referred to the Subway Sewer Department.

RELIEF SEWERS

The first of the large relief sewers to be constructed was the Greene avenue relief sewer, completed in 1892 as far as Marcy avenue, and extended in later years to Halsey street and Evergreen avenue.

Other large sewers are as follows:

South Fifth street sewer, extending from the East river at the north side of the Williamsburg Bridge, 12 feet in diameter, to Union avenue; thence on Johnson avenue, 12 feet in diameter, to Morgan avenue, where it is joined by three large branches 6 feet 6 inches, 4 feet 6 inches and 11 feet in diameter, draining a large area adjoining the Borough of Queens, and diverting, through the Johnson avenue branch, the dry weather flow of the Scott avenue sewer (Brooklyn-Queens Interborough sewer) to the East river.

The Sixty-fourth street sewer, 15 feet in diameter, from the Upper bay to Third avenue; thence on Sixty-second street, 14 feet in diameter, to Fort Hamilton avenue; thence 13 feet 6 inches on Sixtieth street to Fourteenth avenue; thence 13 feet on Sixtieth street to Nineteenth avenue; thence 12 feet on Nineteenth avenue to Fifty-third street; thence on Nineteenth avenue and Foster avenue, 11 feet 6 inches in diameter, to Ocean parkway; thence 11 feet to Coney Island avenue; thence 10 feet to Flatbush avenue; thence on Bedford avenue, reducing from 9 feet to 5 feet, by steps, at Martense street, and to 4 feet at Malbone street. This sewer, recently completed, affords an outlet for the Flatbush sewage to the Upper bay. A storm water relief sewer for this territory will be required in the not far distant future.

The Ninety-second street sewer, 11 feet in diameter from the Narrows, on Ninety-second street, to Fort Hamilton avenue; 10 feet in diameter, to Fourteenth avenue, where a 7-foot 6-inch branch extending out Bath avenue, and an 8-foot 6-inch branch extending out Fourteenth avenue afford outlets for the storm water and sewage of the Bath Beach, Bensonhurst and Dyker Heights districts.

Greene Avenue Relief Sewer. The Greene avenue relief sewer was intended originally to afford relief from flooding in a territory of about 1,300 acres lying west of the ridge of the terminal moraine and south of Greene avenue. Starting with a diameter of 15 feet at the head of Gowanus canal, it traverses Sterling place to Fourth avenue; thence to Hanson place and Raymond street, where the diameter reduces to 14 feet. From Hanson place the sewer is in Greene avenue, maintaining 14 feet diameter to Grand avenue, where it reduces to 12 feet, and to Marcy avenue, where it reduces to 10 feet 10 inches at the terminus of the portion first built. The cost of this portion, including the outlet works at Gowanus canal, was about \$1,000,000. The sewer was subsequently extended, 10 feet 8 inches in diameter, to Patchen avenue, then 6 feet 6 inches to Bushwick avenue, then on Bushwick to Weirfield and on Evergreen to Halsey. A 7-foot 6-inch branch was also extended on Patchen to Hancock, branching there into 6-foot 6-inch and 4-foot 6-inch drains to relieve districts near Broadway and Fulton street, respectively.

The extension of the main sewer to give relief to additional territory greatly overtaxed its capacity, and produced floods and damage at many points.

Additional Relief Sewers. In 1904, owing to the past inconveniences from sewer floods, Mr. John C. Breckenridge, Commissioner of Public Works, was directed to devise a plan to end the causes of the complaints, and Mr. H. R. Asserson, the Chief Engineer of the Bureau, laid out a scheme for relieving the various districts on the following general plan:

1. The admission of one-half of the rainfall, of the district to be relieved, into new sewers.
2. The prevention, by means of intercepting sewers, of the entrance of storm waters into valleys of depression.
3. The construction of sewer outfalls at high enough elevations not to be obstructed during high tides.

Division No. 1 Relief Sewers. The sewers first recommended for construction were what are known as Divisions Nos. 1 and 2, of the main line relief sewers. Division No. 1 included a sewer having its outlet into the Wallabout canal at Classon avenue, and extending 15 feet 6 inches in diameter in Classon avenue, to Park avenue, in Park avenue to Skillman street, in Skillman street to Myrtle avenue, and in Myrtle

avenue to a point east of Bedford avenue. From this point it extended 15 feet in diameter in Myrtle avenue, to Nostrand avenue, in Nostrand avenue to Vernon avenue, in Vernon avenue to Tompkins avenue, and in Tompkins avenue, from Vernon to Greene avenue, where it connects with the Greene avenue relief sewer, which at that place is 10 feet in diameter. This sewer will divert practically the entire storm water flow from the old Greene avenue relief sewer, and discharge it into the Wallabout bay; it has not yet been built.

Division No. 2, Relief Sewers. Division No. 2 comprises a relief sewer having an outlet in the East river at the foot of Gold street, and extending in Gold street 14 feet, to 12 feet 6 inches in diameter from the outlet to Johnson street, and in Johnson street, from Gold street to Hudson avenue; thence 12 feet in diameter in Johnson street, from Hudson avenue to Raymond street; from Raymond street to DeKalb avenue, and in DeKalb avenue, from Raymond street to South Portland avenue. From here it extends 11 feet 6 inches in diameter, in South Portland avenue, from DeKalb avenue to Hanson place. This sewer diverts the entire storm flow as well as the dry weather flow from the Greene avenue relief sewer, thus discharging the house sewage, which formerly emptied into Gowanus canal, into the deep water of East river at the foot of Gold street. A 48 to 54-inch branch extends to Myrtle avenue, from Carlton avenue to Raymond street.

Relief sewers estimated to cost \$7,500,000 were planned at that time, and the Board of Estimate was requested to appropriate \$2,000,000 to start the work. This appropriation was granted in July, 1905, and the Gold street sewer, with a capacity of about 1,000 cubic feet per second, providing relief for a drainage area of about 1,033 acres, has been completed. Division No. 1, which provided for relief for an area of 3.7 square miles of drainage area, has not been completed, owing to the withholding by the Board of Estimate and Apportionment of a portion of the money originally authorized for the work.

With the completion of these two relief sewers and their branches, it is felt by the Bureau of Sewers that the territory penetrated will be properly protected against further damage from sewer floods.

In this connection, it may be well to mention the tunnel now under construction for the relief of the objectionable condition of Gowanus canal.

Gowanus Canal. Gowanus canal is a tidal estuary of the Upper bay, and lies in a north and south direction parallel with Buttermilk channel, and about one mile to the east, its upper limit being about 12,000 feet north of the breakwater at Erie basin. The canal is a dredged creek channel; it is in general about 12 feet deep and 100 feet wide, and has several dredged basins and arms connecting with it that

serve buildings not on the line with the main canal. It affords dock facilities for manufacturing establishments and warehouses in the part of the city that it traverses, and in annual tonnage ranks high among the waterways of the country. There being no definite movement of water in the canal, other than that caused by tides, the condition has been for many years unsanitary, and offensive odors therefrom have been complained of for many blocks away from the canal.

Gowanus Flushing Tunnel. The conditions have gradually been getting worse, until finally it became necessary to provide relief. The plan adopted and now in course of execution, is the construction of a tunnel leading from the head of the canal under Degraw street, to an outlet in Buttermilk channel in the Upper bay, and providing for a circulation of water in the canal and through the tunnel. It is planned to establish a pumping station and pump the water out of the canal into the tunnel, whence it will escape to Buttermilk channel, 6,270 feet away.

The tunnel is now (1910) completed, and plans have been prepared for the pumping station and pumping machinery. Its course is west in Butler street for a thousand feet to Hoyt street, south 500 feet in Hoyt street to Degraw street, and west 4,770 feet in Degraw street to the outlet. The tunnel is circular, with an inside diameter of 12 feet built of four rings of brickwork of a total thickness of 16 inches. The invert is at an elevation $18\frac{1}{2}$ feet below mean high water; this will bring the top $6\frac{1}{2}$ feet below at the outlet. The pumping plant is to consist of a 9-foot propeller type of pump driven by a 400 horsepower motor. The water of the canal will flow to the pump, so that there will be no lift required further than that sufficient to overcome the friction head in the tunnel which is estimated to be $3\frac{1}{2}$ feet. Contracts have been let for the machinery, and it is expected that the plant will be put in operation during the summer of 1910.

It was originally intended to pump from the river into the canal, but for the following reasons it was concluded better to pump in the reverse direction:

1. The principal sources of pollution being at the head of the canal, pumping river water therein would tend to drive these polluted waters out of the canal with the deposition of suspended matter upon the bottom of the canal all the way to its mouth. If, on the other hand, water is pumped from the canal, the polluted waters will be forced out of the tunnel to the river direct at a good velocity, and cleaner water will enter the canal at its mouth to replace that which is pumped out at the head.

2. Loaded boats travel, as a rule, toward the head of the canal and go back empty. A current created in the canal toward its head would materially assist traffic, whereas a current in the reverse direction would be a disadvantage.

3. The top of the tunnel being submerged only 2 feet at low tide at the river end, and the hydraulic slope of the water in the tunnel to the pump being $3\frac{1}{2}$ to $3\frac{3}{4}$ feet, the top of the pump would very likely be exposed at low tide and its efficiency reduced thereby. With a current from the canal to the river through the tunnel, this would not be the case.

4. The tunnel could be used hereafter as an outlet for sewers if it discharges into the river. It could not be so used if it discharged into the canal.

Third Avenue Relief Sewer. A small relief sewer was constructed in Carroll street for the relief of the Third avenue main sewer. This is one block in length and 48 inches in diameter.

Brooklyn-Queens Interborough Sewer. Among the important sewers recently constructed is the sewer in Scott avenue called the Brooklyn and Queens interborough sewer. This sewer provides an outlet for a large drainage area of several thousand acres, the greater part of which lies in the Borough of Queens. It is arranged so that the dry weather flow, or house sewage, will be diverted to the sewer on Johnson avenue, which empties into the sewer discharging into the East river at the foot of South Fifth street. A storm water overflow is provided in Scott avenue, 15 feet 6 inches in diameter, discharging into the head of Newtown creek. Although not the largest sewer in the borough its capacity is greater than that of any other owing to the steep grades. The velocities of flow would have been so great if the sewer had taken the natural slope of the ground south of Flushing avenue, that it was necessary to put in drop-manholes in order to prevent the rapid wear of the masonry and possible damage to the sewer and adjacent property. The outlet at Newtown creek and Metropolitan avenue has been made broad so that the current will not be great enough to prevent boats from lying at the bulkheads when the sewer is discharging at its maximum rate.

Wallabout Channel Relief Sewer. Other relief sewers are planned and it is expected will be put into execution in the near future. Among these is one planned to occupy Flushing avenue and to provide for the abandonment of the three sewers now discharging through the United States Navy Yard into the Wallabout channel.

MAINTENANCE OF THE SEWERAGE SYSTEM

Inspection. The sewers of Brooklyn are not inspected, except as to catch basins, unless in response to filed complaints.

As in Manhattan, steam exhaust pipes are commonly connected to the sewers in the business parts of the city, and although against the law, efforts to have them disconnected have failed.

The cleaning force is adequate to take care of all the small sewers, but more men are needed to properly care for the larger ones.

In 1907 a thorough inspection of the sewers was made and the amount of deposits determined. These were not in all cases as great as had been anticipated, although in several localities they were great enough seriously to reduce the capacity of the sewers.

Designs have been perfected for sewer cleaning machines consisting of steel traveling derricks with gasoline engines and other appurtenances to remove, at one operation, deposited material and load it in carts for disposal. A careful record of costs of all operations is kept.

Basin Cleaning. In 1907, 42,327 basins were examined and 24,389 cleaned. This would indicate an average cleaning of each of the 9,979 basins about $2\frac{1}{2}$ times each year, with an inspection about 4 times each year. The basins in the closely built up and business sections receive attention much more frequently than those in the outlying districts.

The appropriation for the payment of wages of men and purchase of the necessary equipment for cleaning sewers of such faulty design that they require periodical cleaning to keep them in operation was \$55,000 for the year 1908.

Washing of Street Sweepings into Basins. The men of the Street Cleaning Department wash some of the paved streets in certain sections of the city and during this operation much detritus is carried into the catch basins. The custom of pushing street sweepings into the basins appears to be quite general; and, in fact, the basins seem to be popularly considered proper receptacles for anything that will enter the opening, including snow in winter. The report of the Bureau of Sewers for 1907 states that 9,674 basins were cleaned of snow. Although there is an ordinance against putting snow and street sweepings into the basins, the magistrates have invariably dismissed the cases when the street cleaners have been arrested on complaints of the Bureau of Sewers for violation of the ordinances.

Disposal of Basin Deposits. The deposits removed from the catch basins and sewers are carted to public dumps located in sections remote from habitations. In 1907 the deposits removed from basins aggregated 35,272 cubic yards, at an average cost of \$1.63 per basin or \$1.12 per cubic yard.

Store Yards. The Maintenance Department has been much inconvenienced in the past by lack of proper and conveniently located store yards. At present the only yards are the one at North Portland avenue, 50 feet by 100 feet, and the grounds around the disposal plants, miles away from the places where supplies are most frequently and most urgently needed. Recommendations have annually been made by the Superintendent of Sewers, that steps should be taken to secure properly located yards so that



Example of a Sewer Outlet in Jersey City



Sewer Discharging into Gowanus Canal. Conditions in this canal have become so offensive that works have been constructed to pump out the water as the only means of relief

adequate equipment could be provided and a suitable force of men be employed to clean the basins and sewers and properly attend to the general work of the system. At present much time is lost going back and forth after supplies and tools.

DISPOSAL OF THE SEWAGE

The sewage of the territory draining to Newtown creek, the East river, Gowanus canal, Upper bay and the Narrows is discharged into these waters without treatment, dependence being placed on dilution to render the sewage inoffensive and inodorous.

The sewage of the territory draining towards Jamaica bay and the Atlantic seaboard is, for the most part, conducted to plants intended for its purification.

TIDAL DISCHARGE

The disposal into tide water, at certain points, has been attended by the creation of offensive conditions owing to the relatively great quantity of sewage as compared with the flow of water into which it is discharged. In some cases no ill effects have been apparent. The worst conditions are to be found in Newtown creek, Wallabout channel, Gowanus canal and bay, Coney Island creek and the Paerdegat basin. All these are tidal estuaries, or artificially dredged channels in which the movement of water is only that of the rise and fall of the tides. There is no circulation.

Newtown Creek. The condition of Newtown creek needs no minute description. The creek penetrates important manufacturing districts of both Brooklyn and Long Island City, and is lined on both banks with warehouses, elevators and factories of various kinds. Its importance is attested by the fact that the tonnage of the traffic on its surface is greater annually than that of any other single tidal estuary of equal length in this country. Into it is discharged a considerable quantity of manufacturing wastes and the flow of a few sewers. Further discharge of sewage into it is prohibited by law. But in spite of this legal restriction it is to-day in a very objectionable condition.

The outlet of the 15-foot Brooklyn-Queens interborough sewer into the head of the creek at Scott avenue is for storm water only, the dry weather flow of this sewer being diverted into the Johnson avenue sewer which discharges into the East river at the north side of the Williamsburg Bridge in South Fifth street.

Wallabout Bay. The condition of Wallabout bay and channel, particularly where the 9-foot Kent avenue sewer empties into it, is exceedingly offensive at all stages of tide, the bottom of the channel being covered with putrefying sewage sludge and ill-smelling sewage.

The objectionable conditions in Wallabout bay, in front of the Navy Yard, will to some extent be remedied by the interception of the flow of three sewers now discharging

therein and its conveyance into the swift current of the East river at a favorable point of outfall. The work is not yet authorized, although the plans are completed. As soon as the details of the apportionment of the cost as between the borough and the United States Government can be agreed upon, authorization may be expected.

Gowanus Canal. The condition of Gowanus canal, into which the 15-foot Greene avenue relief sewer, as well as some eight other sewers ranging from 1 foot 6 inches to 6 feet 6 inches in diameter discharge has been for some years very offensive. The water is black and foul smelling at all times, and the sides of the piers, bulkheads and masonry structures are darkly discolored.

Coney Island Creek. Coney Island creek receives the effluents of the sewage purification plants back of Luna Park and Manhattan Beach, and the effects of the sewage pollution of the water are decidedly evident.

Paerdegat Creek. Paerdegat creek receives the raw sewage from an area of 4,700 acres in the Flatbush district through four large sewers; one 10-foot sewer from Flatlands avenue; one 7-foot 6-inch sewer from Avenue F; one 3-foot sewer known as the old Kings County sewer; and one 6-foot sewer at Thirty-seventh street and Avenue E. The water of the creek is turbid and discolored and sewage particles can be seen at all times floating about in the water; the creek is in fact an open sewer winding about through a narrow channel between low meadow banks for a mile and a half to discharge into Jamaica bay at a point about half way between Canarsie and Bergen Beach.

Inspections made at the mouth of Paerdegat creek by the Metropolitan Sewerage Commission during the summer of 1909 showed that sewage from the creek sometimes flowed in a visible stream immediately past Bergen Beach. Extensive oyster beds lie in this vicinity.

Effect on Shell Fisheries. Canarsie is one of the principal oyster depots in Jamaica bay. It is said that Jamaica bay produces annually not far from 600,000 bushels of oysters. A large business is done at Canarsie in preparing for market oysters sold in shell and in bulk. The oysters are dredged from the bay, where they have been planted and allowed to grow to marketable size. On arrival at the Canarsie depot they are taken into shanties which line both sides of a small creek to the south of the settled part of the town. Here the oysters are sorted, counted and put into barrels for the half-shell trade or opened and packed into tubs if to be shipped in bulk. It appears that no oysters are drinked in shell here at the present time, although those which are shipped in bulk are immersed in land water after they are opened and before they are put into the receptacles for transportation. This immersion causes the meat to swell and the oysters to look fat.

Pollution of Harbor Waters. From all the large sewer outlets along the water frontage of Brooklyn the sewage discharged can be noted by the discoloration of the water, by solid masses of feces and by the grease on the surface, over extensive areas. In some cases this can hardly be called very offensive, though not pleasant to contemplate, but in others it is both offensive and a menace to health.

Flood tide currents prevent the sewage from flowing out freely and becoming dispersed. As a consequence, at some of the ferry slips, notably at Fulton Ferry, the sewage accumulates to such an extent that the water appears to be all sewage.

Some of the outlets are in the immediate neighborhood of bathing beaches and public floating bathing establishments. At Fort Hamilton the Ninety-second street outlet sewer for the Dyker Heights district is carried out a long distance from the shore, the top of the sewer being above high tide from the shore to its mouth. The sewage discharged therefrom is consequently carried behind the obstruction formed by the outlet as the water flows into and out of the harbor. Bathers are frequently observed swimming in the water at this place surrounded with visible particles of sewage. The same is true of Gravesend bay, of Bath Beach and Ulmer Park, the conditions being unsanitary and dangerous.

On the beach at Norton's Point, near Sea Gate, large quantities of driftwood, garbage and other floating matter collect; these are disposed of by burning on days when the wind blows from the east.

Pollution of Jamaica Bay. In Jamaica bay the outlet of one of the larger Arverne sewers is upon the sloping beach about half way between high and low tide. Men and boys dig in the slimy mud in front of this sewer for soft clams. A little further out, in the direct line of the discharge of the canal carrying the Arverne sewage, is a favorite place for clamming with tongs. On both sides of the causeway at Rockaway, and on both banks, can be seen stakes indicating oyster beds. Shellfish from these places are dangerous to eat or handle.

SEWAGE PURIFICATION PLANTS

In Brooklyn there are four sewage purification plants in operation, as follows:

Plant	Location	Put in service
Caisson No. 2.....	Back of Luna Park, Coney Island.....	May, 1886.
Caisson No. 3.....	500 feet from the highway back of Manhattan Beach.....	October, 1887.
Caisson No. 4.....	Southeast of Sheepshead Bay.....	———, 1892.
26th Ward Plant.....	South of East New York.....	May, 1897.

Coney Island Plants. Caissons No. 2, No. 3 and No. 4 receive the sewage from an area of 1,215 acres, with an average population of about 11,000 and a transient summer population averaging about 350,000. The quantity of sewage treated at Caissons No. 2 and No. 3 averages about 2,500,000 gallons daily, 1,800,000 gallons at the Coney Island, and 700,000 gallons daily at the Manhattan Beach plant. Caisson No. 4 receives the sewage from Sheepshead bay, averaging about 1,750,000 gallons daily. These three plants are operated as a unit and the costs of purification at each can not be separately ascertained from the reports of the Bureau. The works were built under the patents of J. J. Powers. The sewage is treated with lime to hasten the subsidence of the suspended matters in settling tanks. Chlorine gas, manufactured from sulphuric acid, oxide of manganese and salt, is supposed to be used to disinfect the sludge removed from the settling tanks. The effluents from the two Coney Island plants are discharged through the same pipe into Coney Island creek. The cost of operating these three plants in 1907 was about \$26,000.

The process is not efficient, and numerous complaints have been made of offensive odors arising from the discharge into the creek of the ill-smelling effluents, particularly at low tide and when the atmosphere was humid.

Regular analyses have not been made of the sewage at these plants. A report by D. D. Jackson, on samples taken during the week ending December 21, 1907, is as follows:

"The study of the results is somewhat complicated because of the amount of sea water mixed with the sewage. As salt water is used in the high pressure system only in case of emergency, the introduction of sea water into the sewage must be direct. Samples taken on the 15th and the raw sewage on the 16th are very high in chlorine, probably as a result of the high tide following the severe storm on the 14th. The chlorine for the remainder of the samples is still too high, and not explained by the amount of chlorine in the water supply of this section. Two stations, New Utrecht Pumping Station and the Gravesend Pumping Station, supply the water for this district, and this water is also somewhat mixed with water from Ridgewood reservoirs. Probably 100 parts per million is the greatest amount of chlorine which could be obtained from the water supply and the sewage. The remainder must come from sea water. The amount of nitrates present is also low in the first three samples, due to dilution with sea water, and the nitrates in the rest of the samples come from the water supply.

The appearance of some of the treated samples indicated that putrescibility had set in during treatment. The bacteria were somewhat reduced in number, and the intestinal germs in about the same proportion. The inspection of the plant indicated that the chlorine generators had probably not been used for months. The amount of sea water present in the sewage renders it impossible to tell from the analyses whether this is so.

The turbidity is sometimes considerably higher in the treated sewage than in the raw sewage, indicating that the sedimentation basins are quite ineffective."

East New York Plant. The 26th Ward plant, like the two at Coney Island, was built under the Powers patents. This plant receives a larger amount of sewage than any other in the metropolitan district. The territory tributary is at present 3,200 acres, supporting a population of about 100,000, contributing in 1907 some 12,000,000 gallons of sewage daily. The cost of operation for that year was \$32,000; its cost of construction was \$309,000, of which \$255,000 represents the cost of the building.

The building containing the works is circular in plan, and has a diameter of 140 feet. As the sewage enters, it passes through coarse hand-cleaned screens and then enters one of the two semi-circular sets of sedimentation tanks, each tank having a width of 16 feet and a depth of 7 feet. The sewage traverses a distance of 350 feet before reaching the collecting well at the center of the building. The collecting well is 40 feet in diameter, and the bottom is 16 feet below mean high tide. At present it is necessary to keep both sets of chambers in use, and the sewage occupies less than an hour in passing through the plant. From the collecting well pumps lift the sewage about 14 feet and discharge it into an open channel leading to Jamaica bay, a distance of 3,800 feet. Chlorine is used as a disinfectant before cleaning out the sludge, the chlorine being generated by the use of a mixture of 108 pounds of sulphuric acid, 64 pounds of common salt and 48 pounds of manganese dioxide. An aqueous solution of the salt and manganese is first obtained and the acid is then added. The chlorine is discharged at about two pounds pressure. The sludge is discharged upon the meadows in the vicinity of the plant. The lime used in purifying the sewage is used at a rate of one barrel for 200,000 gallons of sewage, and is introduced in the form of milk of lime, after slacking and cooling, at the point where the sewage enters the plant. The working force consists of an engineer in charge, three assistant engineers, three stokers and sixteen unskilled laborers.

The Coney Island, Manhattan Beach and Sheepshead Bay plants are so similar to the 26th Ward plant that the description of this will serve for all the plants.

At the four disposal plants there were used, in 1907, for disinfectants, 7 tons sulphuric acid, 3 tons oxide of manganese, 4 tons of salt; and for precipitants, 3.3 tons perchloride of iron and 5,728 barrels of lime. The total quantity of sewage treated was 5,000,000,000 gallons, from which 4,500,000 cubic feet of liquid sludge was produced, or nearly 1 cubic foot of sludge per 1,000 gallons of sewage.

The sewage appears to be but little improved by passing through the works. The effluent is usually turbid, and solid particles which have escaped removal may be seen on the surface and through the stream.

Quality of effluent. Concerning the character of the effluent from the 26th Ward plant, an examination by the State Board of Health in 1907 shows that it was turbid, contained considerable sediment, and showed evidences of putrescibility in less than thirty hours.

Commenting on the analyses of the effluent from the plant as shown by his analyses in 1907, D. D. Jackson, chemist, says: "These results show that the sewage is strong in character and contains a large amount of fats and other organic matters. The process of purification has not materially reduced either the suspended matters or matters in solution. The presence of hypochlorite (a disinfecting agent) in the effluent, considerably delays the putrescibility. The effluent is, however, putrescible at the end of twenty-four hours."

The outfall flume passes through meadow lands for its entire distance, and at an elevation insufficient to prevent the sewage from flooding the neighboring meadows during high tides.

Inspections of the outfall of the 26th Ward plant by the Commission in the summer of 1909 showed that the sewage passed in a stream along the shores of Jamaica bay in either direction, according to the tidal currents, and has been found to travel as far as Canarsie on the one hand and Old Mill creek on the other, a distance of somewhat more than one mile. Extensive natural growths of soft clams occur and are gathered in this territory throughout the year. They are polluted.

PLANS OF THE BUREAU OF SEWERS FOR THE FUTURE

Realizing the inefficiency of the existing sewage disposal plants, the Chief Engineer of the Bureau of Sewers reported to the Superintendent of Sewers, under date of January 28th, 1908, as follows:

"Beyond any doubt or question, the remodeling of these two plants (Coney Island and 26th Ward) should be undertaken without more delay, the former because otherwise the greatly increased flow of sewage which will reach this plant upon the completion of sewers now under way will create a nuisance in the heart of one of the greatest pleasure resorts in the world; the latter because the present plant (which is at best only a makeshift and a pretense), designed to treat 3,000,000 gallons per day, is now receiving in the neighborhood of 10,000,000 gallons per day, with the result that the sewage flows away from the plant in fully as foul a condition as it reaches it, the

only effect of the treatment it receives being that the effluent contains a quantity of lime, and putrefactive action is delayed several hours.

“Sewers are now authorized and will be placed under contract during the coming season, which, together with the increase in population of the district now tributary to the plant, will eventually double the flow. The effect of this large discharge of practically untreated sewage would be to pollute the shores and shore waters for at least a mile in either direction from the outlet in the neighborhood of a number of pleasure resorts, numerous oyster beds and in front of rapidly developing property.”

In furtherance of the plan to replace these two with modern plants, the Superintendent of Sewers and Chief Engineer of the Bureau visited the principal sewerage works at home and abroad, and subsequently formulated a general program with respect to the disposal of the sewage of the borough. This is as follows:

1. In that part of the borough now draining to East river, Upper bay, the Narrows and a small amount to be pumped from the area near Gravesend, the discharge of untreated sewage to continue, as at present, into tide water. It is intended ultimately to extend all sewers to the pierhead line, and to select points where the currents are swift for points of discharge.

2. In that part of the borough draining to Jamaica bay, Sheepshead bay and Coney Island creek, the sewage is to be conveyed to four purification plants located at the following points:

Name of Plant	Locations
a. Coney Island District	At the site of the present disposal works.
b. Sheepshead Bay District	At the site of the present disposal works.
c. Flatbush District	At Paerdegat basin ; site not yet definitely located.
d. East New York District	On site of present 26th Ward plant at Hendrix street and Van Sicklen avenue.

Proposed Coney Island Plant. It is proposed to first construct the Coney Island plant, for which the plans are completed, the estimates made and the money voted by the properties included in the district. The area covered will be that now draining to the two Coney Island plants, caissons Nos. 2 and 3. It will have a capacity to treat 10,000,000 gallons daily of dry weather sewage flow. Storm water is to overflow to the canal. The plant will be provided with two double sets of centrifugal pumps to raise the sewage first to the hydrolytic tanks, of 2, 4, 6 or 8 hours' capacity, and then, through pumps, to a regulating house from which it will be delivered under head to the cast iron pipe system of the sprinkling filters. The effluent from the filters will

flow by gravity into the settling tanks, of one hour's capacity and thence to the canal. The sludge will be pumped to the sludge tanks or direct to scows, to be towed out to sea.

The special features of the design are:

1. The various means of flushing out the pipes and carrying the flushings back to the hydrolytic tanks rather than to the canal.
2. The staggering of the nozzle outlets so that the area to be covered by the sprayed sewage will be a hexagon instead of a square.
3. The accessibility of all parts of the plant.

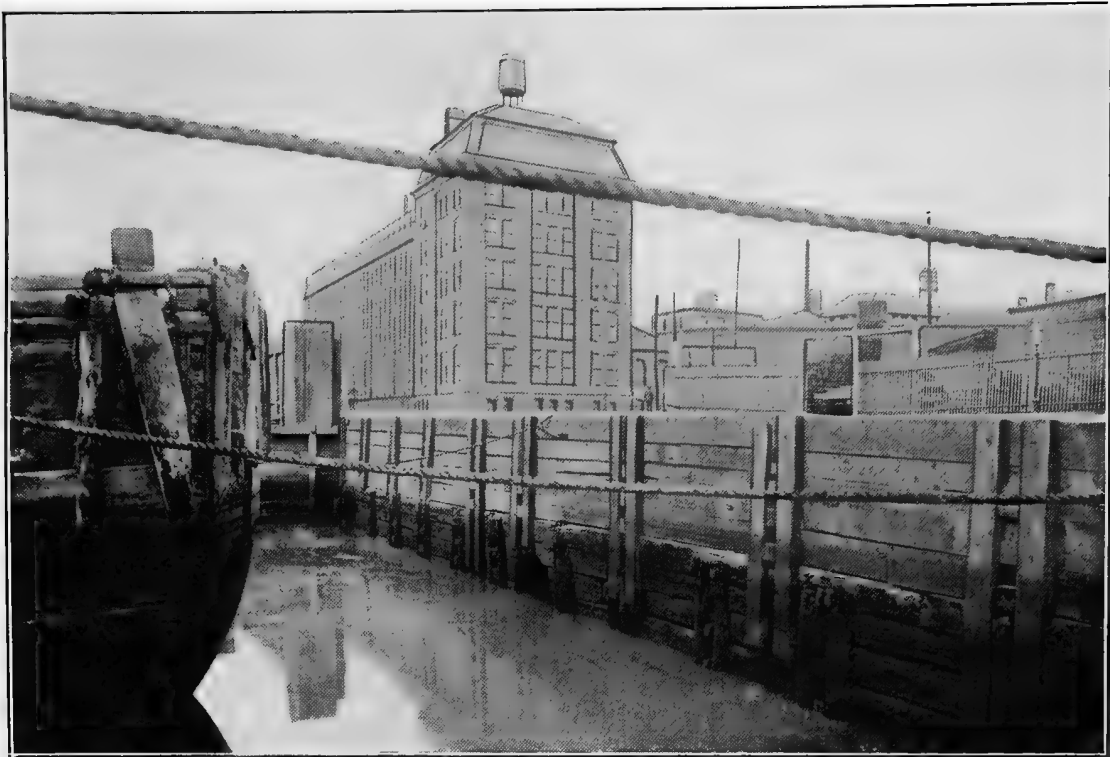
At the time this plant was first suggested Mr. Rudolph Hering, as Consulting Engineer for the Board of Estimate and Apportionment, requested an estimate of cost and operation and advised, as an alternative, to pump all of the Coney Island sewage to sea into deep water off the westerly end of the island; Mr. Dunne, Superintendent of Sewers, requested an estimate for a chemical precipitation plant of the design of the Dublin, Ireland, plant. These estimates, extracted from a report made by Mr. G. T. Hammond, Engineer of Design, to the Chief Engineer, are given in Table VII.

TABLE VII

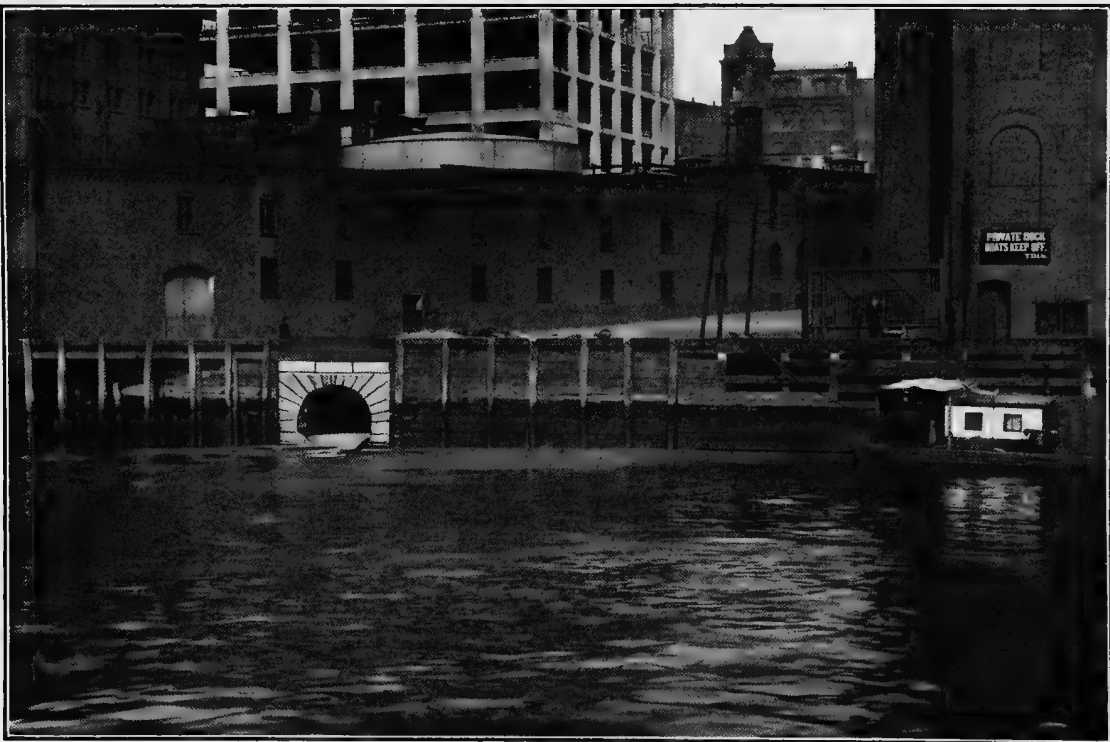
PRELIMINARY COMPARATIVE ESTIMATES OF COST OF CONSTRUCTION AND OPERATION OF DIFFERENT TYPES OF SEWAGE DISPOSAL PLANTS FOR CONEY ISLAND

	Pumping to Sea	Sprinkling Filters			Chemical Precipitation
		2,500,000 gal. per acre per diem. Beds 7 feet deep, 8 hours in sedimentation tank	3,500,000 gal. per acre per diem. Beds 10 feet deep, 8 hours in sedimentation tank	3,500,000 gal. per acre per diem. Beds 10 feet deep, 2 hours in sedimentation tank	
Capacity 10,000,000 gallons per day. Consumption 10,000,000 gallons per day for 4 months and 5,000,000 gallons per day for 8 months.					
Cost of Construction.....	\$241,350	\$619,923	\$561,474	\$416,018	\$284,782
Annual Cost of Operation...	45,664	70,235	66,633	56,451	93,825
Capacity 3,000,000 gallons per day. Consumption 3,000,000 gallons per day for 4 months and 1,500,000 gallons daily for 8 months.					
Cost of Construction.....	\$155,466	\$186,362	.....	.....	\$145,324
Annual Cost of Operation...	35,343	35,755	.....	.....	48,633

The maximum quantity of sewage pumped at the two Coney Island plants in 1906 was about 4,000,000 gallons daily. A 3,000,000-gallon plant therefore would be taxed



Outlets of Sewers in Wallabout Canal



Outlet of Kent Avenue Sewer into Wallabout Canal. The many sewers emptying into this canal have turned it into an open cesspool

to its capacity for a few days each year. A great deal of ground water probably enters the sewers, though no estimate is obtainable beyond a general relation noted between high rainfall and correspondingly large quantities of sewage pumped.

Proposed New 26th Ward Plant. The general plan for the proposed new 26th Ward works is to utilize part of the old plant as a screen chamber and pumping station, and to construct upon the 70 acres owned by the City, in a strip 500 feet wide along the present rotten wooden flume, a canal the materials excavated from which are to form the base upon which to erect a set of sprinkling filters designed on the same plan as those proposed for the Coney Island plant. A capacity of 50,000,000 gallons daily, ultimately to be extended to 73,500,000 gallons daily, is proposed. The plant would deal with the sewage from a drainage area of 6,160 acres.

The plans for this plant have been outlined and could be finished in a short time; but the work is not yet authorized and further expenditures of money for purification works are strongly objected to by property holders upon whom the assessment would fall.

Proposed Paerdegat Plant. The Paerdegat project has not progressed much beyond the study of revising the drainage areas. The exact location has not been determined upon. It would take the drainage from 6,351 acres and have an ultimate capacity of 76,000,000 gallons daily.

Proposed Shellbank Creek Plant. The Shellbank creek plant would be located at the site of the present Sheepshead Bay plant. It would ultimately drain an area of 1,549 acres and have a capacity of 18,500,000 gallons daily. It would be similar to the one at Coney Island, but is not yet designed nor authorized.

BOROUGH OF THE BRONX

GENERAL FEATURES AND CONDITIONS

Principal Topographical Characteristics. The Borough of The Bronx has a total area of 57.2 square miles, of which 18 square miles are water surfaces in the East, Harlem and Hudson rivers with their principal tidewater tributaries, leaving a total land surface of 39.2 square miles. The streams traversing the borough follow a general southerly direction, and discharge into the Harlem river and the East river with the exception of those in a small, narrow strip along the Hudson above the mouth of the Harlem river. In the territory lying west of the Bronx river there are eleven drainage districts exclusive of that tributary directly to the Hudson river. The land lying to the east of the Bronx river is, as a rule, much flatter than the portion lying to the west and includes several square miles of salt meadows between Unionport and Hunts Point, as well as in the valley of Westchester creek and Eastchester river.

The location, the sparseness of the population and the situation with respect to the East river, make this land worthy of consideration in connection with possible future works for the purification of the sewage of territory within reaching distance.

In both districts the ruling characteristic of the topography is that for considerable distances from the outlets at tide water the valleys of the drainage areas are flat, while the sides of the valleys and upper ends are relatively steep and in some places precipitous. This condition renders the construction of sewers for storm water difficult and expensive, requiring, on account of the flat slopes of the valleys, sewers of large size, as the storm water reaches the sewers quickly.

The built-up portion of the borough lies for the most part along the lines of the New York, New Haven and Hartford and New York Central Railroads, and their branches, but the remainder of the territory has in recent years made substantial growth following the improvement in rapid transit facilities.

Distribution of Population. The population of The Bronx in 1905 was 271,592, the principal centers being in the districts known as Port Morris, Casanova, Morrisania, Tremont, Fordham, West Farms, Unionport Westchester, Williamsbridge, Kingsbridge, Wakefield and Woodlawn. It is estimated that not more than one-fourth of the total area of The Bronx is at present occupied by urban and suburban districts, the other three-fourths being in park reservations, agricultural, rural and marsh land districts. The center of population of The Bronx is at present probably in the neighborhood of Crotona Park, some $2\frac{1}{2}$ miles above The Bronx Kills.

General Conditions. Much difficulty is imposed upon sewer construction in this borough by the presence of rock at, and just beneath, the surface of a large portion of the area, as well as large tracts of low-lying land in which the ground water level is higher than the grades of the sewers. In several localities in the lower ends of the drainage areas the ground is unstable and sewers have been ruptured by the settlement of the earth during and after construction.

The streams in The Bronx are all comparatively small, and it has been necessary to keep sewage out of them by means of long trunk sewers. All the towns in The Bronx along the Bronx river discharge their sewage into one or another of the several outlet sewers reaching tide water in the East river.

The principal drainage districts in the borough with their approximate areas in acres and general statistics regarding the outlet sewers therefrom are given in Table VIII:

SEWERAGE OF THE BRONX

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TABLE VIII

DRAINAGE AREAS IN THE BRONX

WEST OF THE BRONX RIVER

Sewerage District No.	Designation of Watershed	Approximate Area Acres	Main Outlet Sewer		
			Street	Diameter of Outfall	Length, Miles
31	Ice pond.....	405	Park ave.....	7' 6"	2.2
32	Third ave.....	190	Lincoln ave.....	4' 6"	0.5
33	Mill brook.....	2,460	Brook ave.....	11' 2"	7.0
34	Bungay ave.....	475	E. 149th st.....	7' 9"	2.0
35	Port Morris.....	275	E. 138th st.....	5' 0"	0.5
36	Leggetts creek.....	915	Tiffany st.....	10' 0"	2.5
37	Cromwells creek.....	1,190	Jerome ave.....	9' 6"	3.1
38	Harlem river.....	720	Fordham road.....	5' 6"	0.7
39	Tibbetts brook.....	2,175	E. 192d st.....	16' 6"	3.0
40	Hudson river.....	630	W. 248th st.....	4' 6"	3.0
41	Spuyten Duyvil.....	285	Spuyten Duyvil.....	5' 6"	1.3
42	Bronx river.....	1,415	Farragut st.....	15' 6"	4.6
	Totals.....	11,135			

EAST OF THE BRONX RIVER

43	Pugsleys creek.....	.....	.....	.....	.....
	Westchester river.....	7,500	Pugsley Ave.....	(Ave E sewer)	}
44	Hutchinson river.....	.....	.....
	Givans creek, etc.....	2,560	Old Ferry Pt.....	.....	.....
45	Weir creek.....	1,350	Throgs Neck.....	.....	.....
46	Pelham Bay Park.....	1,920	.....	.....	.....
47	City Island.....	350	Ends of Streets.....	.....	.....
	Totals.....	13,680			
	Totals.....	24,815 acres=38.8 square miles			
	Detached Islands.....	.4	" "		
	Total area of The Bronx.....	39.2	" "		

Proposed Unionport Sewers. White Plains road into East river; Lafayette avenue into Westchester river, 10 feet by 8 feet, 12 feet by 9 feet, 10 feet by 8 feet.

Relief Sewers. Webster avenue tunnel relief, outlet in Harlem river, 13 feet 6 inches diameter; Truxton street sewer, outlet in East river, 7 feet 3 inches by 11 feet 6 inches.

Bureau of Sewers. The Chief Engineer of the Borough of The Bronx has, in the present organization, three separate bureaus under his charge, one of which is the Bureau of Sewers. The Bureau of Sewers has supervision of:

- (a) Surveys and investigations of all sewer improvements.
- (b) The designs for all new sewerage works.
- (c) The supervision of the construction of sewerage works.
- (d) The maintenance and repairs of the sewers.

Responsibility for the design, maintenance and construction of all sewerage works rests upon the Engineer of Sewers. The designs for sewers in The Bronx have been paid for by the issue of corporate stock; the other boroughs of New York include the expense for sewer plans in the tax levy. Studies are now being made for the preparation of plans for several undeveloped drainage districts east of the Bronx river.

SEWERAGE WORKS

Design. For the territory lying to the west of The Bronx, and which is extensively, although not satisfactorily provided with sewerage, the works are upon the combined plan, making provision to admit both house sewage and storm water. A complete set of lithographed plans of the sewerage in the territory west of The Bronx was published by direction of the Borough President in 1897. These show all the sewers that were constructed at that time, with their routes, sizes, elevations and connections.

The various sewerage systems occupy with slight exceptions the natural watersheds.

For the territory east of the Bronx river no comprehensive plans have been compiled, and, in fact, the drainage plans for the watersheds of this district are now being prepared.

A provision in the Greater New York Charter permits the construction of sewers by private parties or companies who are unable or unwilling to wait for the development of the territory in regular manner. For such sewers the designs are made by or approved by the Bureau of Sewers, which also provides inspectors to look after the construction of the work. When such sewers are completed they are placed under the supervision of the Bureau of Maintenance. This procedure has not been, to any great extent, resorted to in The Bronx.

The formulæ and methods used for the design of The Bronx sewers are similar to those used in the other boroughs, and are given on pages 89 and 90.

No attempt is made in designing sewers in The City of New York to provide for the maximum rain storms, and in order to be protected against further suits for damages due to flooding from inadequate sewer capacity, the approval of plans by the Board of Estimate and Apportionment, when the plans are intended to serve the reasonable needs only of undeveloped territory, is qualified by this note:

“The sewers shown on the drainage plan are intended to have a capacity adequate for the reasonable needs of the drainage district for a limited period, and are not intended to be of adequate size for immediately removing the storm water when the precipitation is at an abnormal rate or when the drainage area shall have become largely or fully improved. The capacity has been thus restricted for the purpose of keeping the cost within limits which it is deemed may be now properly assessed upon property benefited.”

Records of rainfall and excessive rainstorms have been kept by the Bureau of Sewers of The Bronx only since 1904. The quantities of storm water to be provided for have been based upon experience of other cities, upon the formula deduced for Manhattan conditions by Mr. Rudolph Hering in 1887 and 1888, and on the measurements of the velocity of flow in street gutters in the Borough of Richmond.

Sewers. No important troubles were experienced with the older sewers in The Bronx until within about six to eight years. The increase in impervious areas, resulting from the extension of pavements and the increase in roof areas has augmented the quantity, and shortened the time required for storm water to reach the sewers. These two conditions have increased the intensity of flow until some of the sewers have been taxed beyond their capacity.

Brook Avenue Sewer. The principal sewers in The Bronx are those which drain the valleys of Mill brook, Leggetts creek, Cromwells creek, Tibbetts brook and the Bronx river.

The Brook avenue sewer was built about twenty-six years ago, and its construction was a very heavy burden on the taxpayers. Nor was it constructed with the view of providing sufficient capacity for the full development of the territory in which it ran. The construction of a sewer of sufficient size to satisfy completely all future conditions would have been too expensive. This sewer empties into the Bronx Kills, at which point its diameter is 11 feet 2 inches. The invert or floor of the sewer at the end of the outfall is 11 feet below mean high tide; at the shore line it is 8 feet below mean high tide. The bottom of the sewer does not reach the elevation of mean high tide until it has extended to the crossing of the New York and Harlem Railroad, a distance of approximately two miles from its mouth. When the tides are exceptionally high the section of the sewer is completely filled for a

long distance, and when this occurs at times of low stream flow deposits take place in the sewer due to the checking of the velocity. At the present time it is reported that the sediment is from two to three feet in depth in the sewer.

Starting with a diameter of 11 feet 2 inches at the Bronx Kills, the sewer follows Brook avenue to its junction with Webster avenue at One Hundred and Sixty-sixth street, at which point the diameter is reduced to 8 feet 10 inches. It then follows Webster avenue, the diameter being 6 feet at the crossing of the Mosholu parkway, and 4½ feet to Woodlawn road, which it follows to Norwood street, running thence to Perry avenue, which it follows, with the same diameter, to Gunhill road, and with a diameter of 3 feet to East Two Hundred and Eleventh street. On East Two Hundred and Eleventh street it turns west and runs to Woodlawn road, following this to its terminus at about East Two Hundred and Fourteenth street, at the angle between Van Cortlandt Park and Woodlawn Cemetery. At the corner of Perry avenue and Two Hundred and Eleventh street the elevation of the invert is 134½, and at Mosholu parkway the elevation is 50 feet, a fall of 84½ feet in a distance of about a mile. The total slope in the remaining six miles of the sewer is only 50 feet. This indicates in a general way the nature of the valley through which the sewer runs, and offers an explanation of some of the difficulties that have been had with its operation.

The deposits that form in this sewer have been the source of a good deal of trouble, for the reason that the Maintenance Department of the Bureau of Sewers can not furnish enough men to clean it or to keep it clean, the volume of material to be removed is so large. It is stated that at one time a contract was let for the removal of 5,000 cubic yards of deposits from this sewer, and that when the contractor had finished, there was practically as much deposit left in the sewer as when he began. Requests for funds for the cleaning of the sewer have been asked for of the Board of Estimate and Apportionment, but have not been provided. During storms of more than moderate intensity, the sewer becomes choked, and finds relief for the pressure by discharging through the manholes and flooding the streets and adjacent properties.

Broadway Outlet Sewer. The sewer which drains the valley of Tibbetts brook and discharge into the Harlem river at East One Hundred and Ninety-second street, is one of the largest sewers in The Bronx, having a diameter of 16 feet 6 inches at the outfall. It follows Exterior street northerly to Broadway, and along Broadway to West Two Hundred and Thirty-fourth street, with a diameter of 15 feet, reducing to 14½ feet at West Two Hundred and Thirty-sixth street, and 14 feet at West Two Hundred and Forty-first street, where its diameter is reduced to

71¼ feet as far as West Two Hundred and Forty-second street. From West Two Hundred and Forty-second street it has a diameter of 7 feet to the junction of Newtown avenue, and from thence to Two Hundred and Sixty-first street it gradually reduces in size in accordance with the reduction of the drainage area to a diameter of 3 feet, where provision is made for taking in a small amount of drainage from Yonkers if necessary. This sewer is a concrete steel structure at its lower end, with a section equivalent to a circle of 16 feet 6 inches in diameter. Its diameter, however, is not sufficient to take care of the entire drainage area when Tibbetts brook shall have been turned into it, and when the tributary territory shall have become fully developed. It is contemplated that in the future, relief sewers may be needed for this district.

Farragut Street Sewer. The Farragut street sewer discharges into the East river on Farragut street nearly opposite Rikers Island. It has a cross section at the outlet equivalent to a circular area 15 feet 6 inches in diameter. This sewer drains what is designated as the Bronx river watershed, a strip about a half mile wide west of The Bronx, extending from Hunts Point on the East river, to St. John's College, a distance of 4.6 miles. The sewer follows along the Hunts Point road to Whittier street, and thence to the West Farms road and Boston road to East One Hundred and Seventy-eighth street, where the diameter is 7 feet. It then runs west on One Hundred and Seventy-eighth street to the Southern boulevard, which it follows to East One Hundred and Eighty-seventh street, which it follows for several blocks, being finally reduced to a diameter of about 2½ feet. The outlet of the Farragut street sewer is placed high enough to prevent its tide-locking.

Tiffany Avenue Sewer. The Tiffany avenue sewer empties into the East river at a point about three-quarters of a mile to the west of the Farragut street sewer. It has a diameter of 10 feet at the point of discharge, and the end of the outlet is submerged. It follows Tiffany street to Spofford street, and thence along Longwood road to the Southern boulevard and Intervale avenue, at which point its diameter is reduced to 8 feet. It then follows Intervale avenue for the rest of its course to the side of Crotona Park, where it ends with a diameter of 4 feet. The tributary watershed of this sewer, which occupies the valley of Leggetts creek, is 915 acres. The length of the sewer is about two and one-half miles. The invert or sewer bottom is practically above high tide, excepting for the first half mile.

Jerome Avenue Sewer. The sewer discharging into the Harlem river at Jerome avenue drains the valley of Cromwells creek which has a watershed of 1,190 acres. At the point of discharge the sewer is 9 feet 6 inches in diameter. It follows Jerome ave-

nue for its entire length, with the exception of about 2,000 feet. Its total length is about 3.1 miles. This is one of the sewers the outlet of which is tide-locked.

East One Hundred and Forty-ninth Street Sewer. The sewer outletting into the East river behind North Brother Island in One Hundred and Forty-ninth street, drains the Bungay creek watershed, which has an area of 475 acres. The sewer is 7 feet 9 inches in diameter at its mouth, and extends back about two miles from the water-front.

Sewers of Unionport. Outlet sewers of large size compared with the immediate needs of the Unionport district, which occupies a portion of the sewerage district No. 43, have been and are now being constructed. Appropriations have not yet been approved for lateral sewers to connect with these trunk lines. There are very few sewer outlets at present in the territory of The Bronx east of the Bronx river. Those now ready for contract, or under construction, are the outlet on Lafayette avenue, in connection with the sewer on Avenue A (Zerega avenue), Lafayette avenue, Avenue B (Havemeyer avenue), Lacombe avenue, and the outlet at the White Plains road for the sewers on that road, as well as the dry weather flows of the Avenue A and Avenue E sewers, which at present go into Westchester river and Pugsleys creek, respectively. The Lafayette avenue outlet has a triple section; the two outside openings are 10 feet by 8 feet, and the central one 12 feet by 9 feet in section. A connection will join the Lafayette avenue, Avenue E and White Plains road sewers, through which the house sewage from each of these large sewers will be conducted to the White Plains road outlet into the East river. The Avenue E sewer is in duplicate, each part being 10 feet 6 inches by 8 feet in section. It is completed to the intersection of Avenue E and Randall avenue. Storm water flows in the Avenue E sewer will be discharged in the Pugsleys creek and the storm water from the Avenue A sewer will be discharged into Westchester creek at the foot of Lafayette avenue. Both the Lafayette avenue and Avenue E sewers now have temporary outlets for all sewage.

An area of 7,500 acres is included in drainage district No. 43, ultimately the whole of which will outlet at the points indicated above.

Unionport and Westchester have sewers on the separate system, or storm water drains only. It is said that undoubtedly a great many house connections are made direct to the storm water drains on rain water permits.

City Island Sewers. There are no city sewers for domestic sewage on City Island. Plans have been made to extend sewers out into the Sound at the foot of each street. The Highway Department has just graded and paved the main street, running lengthwise of the island, and a storm water drain running to either end has been installed. It is thought a number of house connections have been made to this drain.



Newtown Creek. The tonnage of traffic here is greater than on any other single tidal estuary of equal length in the United States



Typical scene Along the Waterfront of Manhattan and Brooklyn in Summer

Catch Basins. At street intersections and low places in the street grades the surface waters are taken into the sewers from the streets through catch basins of the type of construction usual in New York. It is problematical how much benefit results from the use of catch basins in connection with sewers such as the Brook avenue sewer, for instance. That they do not hold back the surface detritus effectively is evident from the fact that even with a large gang of men at work cleaning the sewers, it is impossible to make any perceptible impression on the two to three feet of sediment in its bottom.

Ventilation. Ventilation, such as is secured in most of The Bronx sewers, takes place only through the holes in the manhole covers. The entrance of air into the sewers by way of the outlets is prevented in 30 per cent. to 50 per cent. of the sewers by the submergence of the outlet beneath the surface of the water.

The air in some of the sewers is so contaminated as to prevent entrance for inspection. An example of this condition is to be found in the case of the Park avenue sewer, into which it has been practically impossible to enter for a number of years owing to the discharge into it of gas wastes.

Flushing. There are four flush tanks on the sewers in The Bronx. These are on sanitary sewers west of The Bronx where the separate system has been used to a limited extent. In addition to the regular flushing by tanks, the sewers are occasionally flushed out with a stream from a fire-hose.

Outfalls. The sewers of The Bronx all discharge by gravity into either the Hudson river, the Harlem river, Bronx Kills or the East river. The discharge in most cases takes place at the bulkhead line, and at least one-third of all the existing outfalls are at so low an elevation as to be tide-locked, and filled with back water for a great length. The Brook avenue sewer, for instance, is subject to backwater for about two miles of its length.

The newer and more recent sewers are provided with more satisfactory outfalls than many of the older ones, but the problem involves, in many instances, much difficulty in the matter of construction.

DATA COLLECTED

TABLE IX
OUTLETS OF THE SEWERS OF THE BRONX

Location	Diameter	Elevation of Invert at Outfall*	
<i>Into the Hudson River—</i>			
West 261st street.....	2' 6"	—6.0	—9.5
West 254th street.....	4' 0"	—6.0	—11.0
West 248th street.....	4' 6"	—6.0	—11.5
West 247th street.....	1' 6"	—6.0	—8.5
West 236th street.....	3' 9"	—6.0	—11.0
<i>Into the Harlem River—</i>			
Near Hudson river outlet.....	2' 6"	—1.0	—9.0
Main sewer Spuyten Duyvil.....	5' 6"	—6.0	—12.0
Kingsbridge road (temporary outlet).....	5' 6"	—1.0	—11.0
East 192d street.....	16' 6"	—6.0	.....
East 191st street.....	1' 0"	—7.5	.....
Fordham road.....	5' 6"	—1.0	—11.0
East 178th street.....	4' 9"	—6.0	—11.0
East 177th street.....	1' 6"	—5.0	—8.0
East 176th street.....	3' 6"	—5.0	—10.5
East 171st street.....	2' 6"	—4.0	—9.5
Webster avenue relief tunnel.....	13' 6"	—5.94	.....
Depot place.....	1' 0"	—2.0	—8.0
East 167th street.....	4' 0"	—5.0	—10.0
East 164th street.....	1' 6"	—2.0	—8.0
Jerome avenue.....	9' 6"	—6.0	—12.0
East 150th street.....	3' 0"	—6.0	—9.5
East 149th street.....	5' 0"	—6.0	—12.0
East 138th street.....	2-1' 0"	0.0	—7.0
Park avenue.....	7' 6"	0.0	—13.5
Third avenue.....	2'8"x4'0"	—3.76	.....
Lincoln avenue.....	4' 6"	—3.4	—11.
<i>Into Bronx Kills—</i>			
Brook avenue.....	11' 2"	—8.0	—11.0
Cypress avenue.....	2' 6"	—6.0	—9.0
Willow avenue.....	1' 6"	—3.0	—8.0
Walnut avenue.....	2' 6"	—4.5	—9.0

* The elevations of the inverts are expressed in feet below mean high tide at the Third Avenue Bridge across the Harlem river the figures in the first column refer to the elevation of the sewer at the bulkhead line; those in the second column to the elevation of the invert of the outfall section.

SEWERAGE OF THE BRONX

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TABLE IX—*Continued*

Location	Diameter	Elevation of Invert at Outfall*	
<i>Into the East River—</i>			
Locust avenue.....	1' 3"	0.0	—8.0
East 132d street.....	1' 0"	0.0	—1.5
East 134th street.....	3' 6"	—5.0	—9.5
East 135th street.....	1' 0"	.....	.....
East 136th street.....	1' 0"	.....	.....
East 137th street.....	1' 0"	.....	.....
East 138th street.....	5' 0"	—5.0	—11.0
East 139th street.....	1' 0"	.....	.....
East 140th street.....	1' 0"	.....	.....
East 149th street.....	7' 9"	—5.0	—11.0
Cabot street.....	1' 0"	.....	.....
Dupont street.....	4' 6"	—6.0	—11.0
Truxton street (relief for East 149th street).....	11'6"x7'3"	.....	.....
Tiffany street.....	10' 0"	—6.0	—12.0
Manida street.....	4' 0"	—6.0	—11.0
Farragut street.....	15' 6"	—6.0	.....
Ryawa.....	6' 0"	—6.0	—13.0
White Plains road (proposed).....	.....	.....	.....
Lafayette avenue **(proposed storm water overflow for Avenue E)	10'0"x8'0"	.....	.....
	12'0"x9'0"	.....	.....
	10'0"x8'0"	.....	.....
Old Ferry Point.....	No data as to area drained.		
Throgs Neck.....	No data as to area drained.		
City Island.....	Four small sewers discharge to tide water.		

*The elevations of the inverts are expressed in feet below mean high tide at the Third Avenue Bridge across the Harlem river; the figures in the first column refer to the elevation of the sewer at the bulkhead line; those in the second column to the elevation of the invert of the outfall section.

** The Lafayette outlets take storm water from Havemeyer, Zerega and Lafayette avenues to Westchester creek. The Avenue E outlet for storm water is into Pugsleys creek; the White Plains outlet is to take its own storm water and the sanitary sewage from Lafayette, Avenue E and White Plains road districts.

Growth of the System. The number of miles of sewers built in The Bronx each year, and the totals since 1874, are given in Table X:

TABLE X
GROWTH OF THE SEWER SYSTEM IN THE BRONX

Year	District West of Bronx **		Whole of Borough		District West of Bronx		East of Bronx	
	Receiving Basins Built	Total to Date	Miles of Sewers Built	Total to Date	Miles of Sewers Built	Total to Date	Miles of Sewers Built	Total to Date
1874		130		3.24		3.24		
1875	567		33.39	36.63	33.39	36.63		
to								
1890		697						
1891	819				73.32			
1892								
1893								
1894								
1895								1.43
1896				115.44		109.95	4.06	
1897		1,516						5.49
1898								
1899	621				62.07		4.18	
1900								
1901		2,137		181.73		172.02		9.71
1902	120	2,257	13.75	195.48	9.21	181.23	4.54	14.25
1903	170	2,427	16.24	211.72	6.85	188.08	9.39	23.64
1904	85	2,512	12.06	223.78	5.64	193.72	6.42	30.06
1905	128	2,640	12.56	236.34	9.87	203.59	2.68	32.74
1906	118	2,758	11.11	247.45	9.32	212.91	1.80	34.54
1907	133	2,891	11.51	258.96	10.97	223.88	.54	35.08
1908	120*	3,011*	11.04*	270.00				

* Board of Estimate Report, 1908.

** There are no basins reported for the district east of the Bronx river.

Construction Difficulties. A great deal of trouble has been experienced on filled and marshy ground where it has been necessary to put embankments over the sewers after completion, by mud-waves, which, in places, have eventually wrecked the structures. It is now the practice to first construct and compact the embankments and build the sewers in excavations made therein.

Plans of Local Authorities for Future Work. Plans for future work contemplate, in general, the detailed designing and working up of details of sewerage for Drainage District No. 43, with its 7,500 acres outletting at Classon point, and Drainage Districts Nos. 44 and 45, having 2,560 and 1,350 acres respectively and outletting at Old Ferry Point and Throgs Neck.

RELIEF SEWERS

For a number of years trouble has been experienced in various of The Bronx sewers, owing to congestion and consequent floods. In 1901 two particularly heavy storms caused a good deal of damage by flooding. As a consequence, steps were taken to relieve the Brook avenue sewer, as well as the territory in Bungay creek, Leggetts creek and Mill brook watersheds.

Webster Avenue Relief Tunnel. The plan for the relief of the Brook avenue sewer, which has been put into execution and is now (1910) about three-fourths finished, is to divert the entire flow of the Webster avenue sewer into a tunnel at Webster and Wendover avenues, passing westward and discharging into the Harlem river a short distance above High Bridge. The tunnel is to be about 6,800 feet long and have a cross section equivalent to that of a circle 13 feet 6 inches in diameter. It is planned to close up the section of the old Brook avenue just below Wendover street when the tunnel is ready to use. Even with the relief provided by this tunnel it is stated that before many years it will be necessary to construct still another sewer parallel with the Brook avenue sewer.

When the Brook avenue sewer was stripped of covering to make connection with the new Webster avenue relief tunnel a very heavy flow, due to a rainstorm, occurred coincidently with high tide, the sewer became overtaxed, and the added pressure blew off the arch ring and flooded the tunnel work. This is the first time the sewer has broken, the discharge into the streets through the manholes heretofore having given sufficient relief.

Truxton Street Relief Sewer. The Truxton street relief sewer is a reinforced concrete structure of a horseshoe section 7 feet 3 inches by 11 feet 6 inches. It was built to afford relief to the sewers of the Leggetts creek and Bungay creek watersheds.

MAINTENANCE OF THE SEWERAGE SYSTEM

Inspections. The organization of the maintenance force does not include regularly appointed inspectors of basins and sewers; the foremen in charge of the cleaning gangs, however, inspect basins where cleaning operations are going on and investigate immediately the causes of such complaints.

Cleaning Sewers. Sufficient funds are allowed for cleaning basins and smaller sewers, but for large sewers, such as the Brook avenue sewer, special appropriations are much needed. The work of cleaning is done by day labor rather than by contract, and by hand, no sewer cleaning machines being in use. In 1907 the force examined 76,170 lineal feet and cleaned 32,467 lineal feet of sewers, and examined 37 and cleaned 1,053 basins. There being then 2,891 basins, each was cleaned about three times during the year.

Cleaning Catch Basins. In the various reports no basins are credited to the territory east of Bronx river. Quite a number, however, have been built by the Bureau of Highways, and are or will be connected to the sewers. Recently the same design as used by Bureau of Sewers has been used by Bureau of Highways. The basins are turned over to the Bureau of Sewers to maintain when connected. Everything goes into the basins just the same as in the other boroughs. The law against this seems to be a dead letter, as the Magistrates discharge all such cases. The cleanings from catch basins, which consist very largely of sand and earth, are used for filling. The sewer cleanings in many cases are hauled to the garbage barges.

Steam in Sewers. Connecting steam exhaust pipes to the sewers is practiced, but there is not enough going into sewers at present to cause any complaint. It does not show to any extent from manholes in winter.

DISPOSAL OF THE SEWAGE

Tidal Discharge. The sewage of The Bronx is discharged into the tidal waters surrounding the borough without treatment of any sort. At the present time there are no purification plants within the limits of the borough, although there are some few small ones in the valley of the Bronx river above the city limits.

No definite plans for sewage disposal other than as at present, into the Harlem and East rivers, has been proposed. The Harlem river waterfront is occupied largely by railroads; and the East river and Sound front has not been developed, so that complaints are very rarely, if ever, heard against the present method of disposal, although sleek from the Farargut street outlet has been noted in the East river flowing past Classon point.

The condition of the Harlem and East rivers as described in connection with the sewerage of Manhattan, is so unsatisfactory that a plan for their protection is an immediate necessity.

A recent communication from the Board of Estimate and Apportionment to the Bureau of Sewers of The Bronx asked for information as to the feasibility and costs of building screening devices at the end of each outlet sewer, but no money was appro-

priated for the investigation and report, and it was impossible to supply the information, although it is believed by the Bureau of Sewers that some other disposition or treatment of The Bronx sewage than is now practiced will ultimately be needed.

BOROUGH OF QUEENS

GENERAL FEATURES AND CONDITIONS

Principal Topographical Characteristics. The Borough of Queens is approximately trapezoidal in shape, the smaller end bordering on Jamaica bay. The borough, which has an area of 117 square miles, and had in 1905 a population of 197,838, includes a number of small towns.

The high ridge of the terminal moraine, rising from 160 to 180 feet above sea level, extends across Queens from Forest Park to a point about a mile north of the town of Queens. The only exposure of crystalline rocks on Long Island occurs in Long Island City and in the immediate vicinity of Hell Gate. Flushing bay creek indents the northern portion of the borough and Newtown creek forms the southern boundary of Long Island City.

There are three main populated districts:

1. Long Island City and the territory as far to the east and south as Flushing creek and Forest Park;
2. Flushing and all the territory north of the ridge of hills;
3. Woodhaven, Richmond Hill, Jamaica and all territory to the south of the ridge of hills.

One portion of the Long Island City area drains into East river; a second portion southwest of the line of cemeteries drains into Newtown creek, and the third, including Elmhurst and Newtown and contiguous areas drains into Flushing creek.

Of the Flushing territory, one portion drains into Flushing creek or the bay; a second, at College Point, drains into the bay and East river; a third, at Whitestone, drains into the East river, and a fourth and last, at Bayside, drains into Little Neck bay.

All of the Jamaica territory drains into Jamaica bay.

Municipalities in the Borough. Little information can be had regarding the earlier Queens borough sewers for the reason that no comprehensive plans have yet been outlined, each small territory having been heretofore considered by itself. Numerous small systems have been independently built, each of which presented its own special difficulties. Statistical data of some twenty-nine towns in the five wards which make up the Borough of Queens, together with their areas and the status of street surveys, at time of consolidation, are given in Table XI.

TABLE XI

STATISTICAL DATA, BOROUGH OF QUEENS

Ward	Location	Towns	Area in square miles	Condition of surveys at time of consolidation
First . . .	Long Island City . . .	Hunters Point Blissville Dutch Kills Ravenswood Astoria Steinway Total of Ward . .	7.4	Street systems and grades established
Second . .	Newtown Township . .	Ridgewood Melvina Woodside Newtown Corona Middle Village Maspeth Laurel Hill Glendale Total of Ward . .	22.0	Nothing
Third . . .	Flushing Township . .	Flushing College Point Whitestone Bayside Total of Ward . .	30.5	Few inefficient maps of little engineering value
Fourth . .	Jamaica Township . .	Jamaica Woodhaven Queens Richmond Hill Hollis Springfield Total of Ward . .	48.1	Contour and grade map of Jamaica village only



The East River Entrance to the Harlem River. A 10-foot sewer discharges under the pier on the left. To the right is one of the City's recreation piers



The Harlem River. By the year 1940 this river will receive the sewage of more than one and one-third million people

TABLE XI—*Continued*

Ward	Location	Towns	Area in square miles	Condition of surveys at time of consolidation
Fifth...	The Rockaways.....	Rockaway Park		Nothing
		Arverne		
		Edgemere		
		Far Rockaway		
		Total of Ward..	9.3	
	Grand Total.....		117.3	
	Dry land.....		104.9	
	Land under water.....		12.4	

From 1902 to 1904 a number of trunk combined systems were planned in response to popular demands; but as it soon became evident that the construction of sewers of the enormous size required for some of the sparsely settled suburban districts would involve expenditures so large as to be all but prohibitive, the Board of Estimate and Apportionment urged that expert studies be made of the whole territory. Consequently, in June, 1907, Mr. Rudolph Hering was asked to advise the Board of Estimate and Apportionment on various sewerage plans, and his services in similar connections were also made available to the Borough Presidents and to their sewerage engineers. Investigations and recommendations were made by Mr. Hering regarding the existing sewage disposal plants and the drainage plans in Queens.

Bureau of Sewers. The Bureau of Sewers is organized similarly to that of Brooklyn. The Superintendent of the Bureau has direct supervision of the maintenance of the sewers and the disposal plants. The Chief Engineer or Engineer in Charge, as he is technically called, has charge of the design, construction and inspection of all new work and the making up of the assessment rolls. The maintenance department consults the engineers for repair work of any magnitude. A movement is planned to reorganize and unify the departments by having the heads of the various bureaus report directly and frequently to the Commissioner of Public Works.

The Superintendent of Sewers and his foremen are appointed; the engineering corps is under civil service regulations. It consisted in 1908 of the following:

1 Chief Engineer, 7 Assistant Engineers, 2 Transitmén, 6 Draftsmen, 1 Draftsman's Helper, 2 Rodmen.

An appropriation of \$17,000 was apportioned for studying various drainage problems in 1909, but heretofore the force has been too small to do more than keep up with local problems. In consequence the records of the system in Queens are incomplete.

SEWERAGE WORKS

Old Sewers. All the old sewers were designed as combined sewers except those in the towns of Jamaica, Elmhurst and Far Rockaway. Many of the smaller ones were privately built by plumbers and have all kinds of grades and alignments. The larger sewers were generally built of brick and the smaller ones of vitrified pipe. In recent years private construction under the special provision of the Charter has been carried on in the Ridgewood territory. Some of these plans do not conform to the accepted drainage plans and at some future time the property owners will be called on for further assessments to duplicate lines they are now using. Complete records of all sewers and basins do not exist, but the Bureau is securing the location of old ones as fast as possible with the limited force available. It is reported that in White-stone and Bayside a number of sewer manhole heads were buried when the roads were graded and improved and as no records or plans of these sewers are in the possession of the Bureau of Sewers the full extent of these systems is unknown.

Design. The formulae used for determining the sizes of the sewers are given on pages 89 and 90, but they are not adhered to strictly in working out the various problems as other local factors are usually also considered. It is the intention to take up a study of the rainfall and run-off this season to determine the variations due to the high ridge of hills running through the the borough.

It has been necessary to rely upon the records in the other boroughs and in other cities heretofore. The Brooklyn-Queens interborough sewer in Myrtle and St. Nicholas avenues is said to have been designed to take care of its whole drainage area at its maximum rate of run-off.

A number of maps in the Bureau's keeping show the various drainage districts on a scale of 200 feet to the inch, but one map showing the whole borough is not available. The layout of streets and street grades has been carried forward without regard, in many cases, to drainage necessities.

TABLE XII

THE LOCATION AND SIZES OF THE SEWER OUTLETS IN THE BOROUGH OF QUEENS

Location	Point of Discharge	Size, or Equiv. Circular Diameter	Remarks
Seneca avenue	Newtown creek	16'0"	Storm water " "
Greenpoint avenue	" "	24"	
Pearsall street	" "	24"	
East avenue	" "	4'2½"x3'3"	
Vernon avenue	" "	24"	
8th street	East river	4'2½"x3'3"	
Mott avenue	" "	4'2½"x3'3"	
Harris avenue	" "	7'8"x7'7"	
Freeman avenue	" "	2'30"	
Webster avenue	" "	14'0"	
Broadway	" "	16'0"x7'0"	Storm water
Main street	" "	3'0"	
		3'6"x2'8"	
Wardell street	Hell Gate	12"	
Hoyt avenue	" "	8'0"x12'0"	
Woolsey avenue	" "	18"	
Potter avenue	" "	15"	
Ditmars avenue	" "	18"	
Wolcott avenue	" "	15"	
Hoffman boulevard	Elmhurst Disposal Plant.	5'0"	Disposal Plant Drains 450 + acres
West street and Jamaica road	Flushing creek	9'0"	
Broadway	" "	18"	
		24"	
Grove street	" "	5'0"	
Myrtle avenue	" "	24"	
5th avenue	Flushing bay	5'0"	
College Point	East river	24"	
N. 28th street	Powells cove	18"	
14th avenue	East river	24"	
Broadway	Little Neck bay	Disposal Plant Drains 450 + acres
Leland avenue and Remsen avenue	Far Rockaway	10"	
Old (So.) road and road to Bergen Island	Jamaica	2'9"	

Elevation of Outlets. Almost without exception the outlets of the Queens sewers are submerged at high tide. If the grades are flat the tide may back up a mile; *e. g.*, the Webster avenue 14-foot combined trunk sewer, which, in consequence of its flat grade, has about 2 feet to 3 feet of sediment on the bottom; but as this is not taxed to probably half its capacity no flooding has occurred. Submerged sewers are designed for the pressures they must withstand. At College Point a 30-inch wooden barrel sewer outlets 1,100 feet from shore and 16 feet below mean low tide.

Materials. In the last three years all the large sewers have been built of reinforced concrete. The Queens-Brooklyn interborough sewer, draining the Ridgewood area, is of reinforced concrete in Queens and concrete invert and brick arch in Brooklyn.

Ventilation. It is the intention to use perforated manhole covers and to build all sewers with the roof in an unbroken line, so that air may sweep through from manhole to manhole.

Flush Tanks. There is one flush tank in the system, but it is now shut off. The use of flush tanks is not advocated by the local authorities in Queens.

NEW SEWERS

Area North of Newtown Creek. The area north of Newtown creek between the Long Island Railroad and the cemeteries used to drain into Newtown creek prior to the regulations prohibiting the emptying of house sewage into that stream. A new sewer to carry up to four times the dry weather flow of this section has been built under the Long Island Railroad tracks and carried to the East river.

Ridgewood Area. The Ridgewood area and adjoining areas of about 4,600 acres, are drained by the so-called Brooklyn and Queens interborough sewer. It has an outlet diameter of 15 feet 6 inches, emptying at the head of Newtown creek in Brooklyn. The dry weather flow of this sewer is carried through the Brooklyn sewers to an outlet into the East river at South Fifth street. The estimated cost of the 5,700 feet of this sewer in Brooklyn was over half a million dollars.

Flushing. A large 9-foot 6-inch trunk combined sewer draining the Ingleside area of about 1,200 acres was constructed with a storm water outlet into a tributary of Flushing creek, but provision for a disposal plant was not carried out as originally intended and a temporary outlet into the creek was proposed and rejected. It has been proposed that a trunk sewer be constructed to take the whole of Flushing's sanitary sewage and discharge it into Flushing bay at the foot of Myrtle street for a limited period, carrying it ultimately into deep water off College Point. There is now on foot a plan to treat the dry weather flow near Flushing creek at the foot of Fowler street, the storm water to overflow at other points, further back, into the creek.

GENERAL DESCRIPTION OF SEWERAGE

The following is a brief statement, extracted from an article by Alberto Schreiner, C. E., in the 1908 Proceedings of the Municipal Engineers of The City of New York, respecting the sewerage systems in Queens.

FIRST WARD, LONG ISLAND CITY

EXISTING SEWERS

Hunters Point System. Was largely built in 1876; its capacity is now becoming insufficient.

Harris Avenue Trunk Sewer. Built in 1896, it is 7 feet 8 inches by 7 feet 7 inches in size; half of the drainage system is still undeveloped.

Webster Avenue Trunk Sewer. Completed in 1903, this sewer has a twin horseshoe section equivalent to a circular section 14 feet in diameter. Numbers of its lateral branches have been built.

Broadway System. Trunk outlet built in 1896; size, 16 feet by 7 feet. The sewer is in poor condition. The system of laterals or collecting sewers is nearly complete.

Hoyt Avenue Sewer. Size, 8 feet by 12 feet; system nearly complete.

PROPOSED SEWERS

Theodore Street. Size, 12 feet 6 inches; trunk sewer to discharge at the bulkhead line, 3-foot 6-inch dry weather outlet to discharge at pierhead, 1,400 feet distant, in Bowery bay.

Blissville Section. The sewage will require pumping to East river under Dutch Kills.

SECOND WARD, NEWTOWN

Few sewers have been built in this section. The following are the most important:

Queens-Brooklyn Interborough Sewer. Size, 15 feet 6 inches at outlet. Receives the sewage from 4,500 acres; dry weather flow to be diverted, at Scott avenue, into Brooklyn sewer discharging into East river at South Fifth street. Storm water to overflow into Newtown creek.

Hoffman Boulevard to Elmhurst Disposal Plant. Size, 5 feet. Will need to pump the effluent at some future date.

THIRD WARD, FLUSHING

Sewers in old section of Flushing inadequate and should be rebuilt.

Ingleside Section. Area, 1,200 acres. Trunk sewer, 9 feet 6 inches diameter, building. Dry weather flow to be treated.

College Point. Efficient combined system. Thirty-inch wooden flume outlet extends 1,100 feet out from shore in 16 feet of water at mean tide.

Several smaller sewers discharge on flats and produce nuisances.

Several new sewers are planned at College Point with outlets to deep water; certain existing outlets to be extended to deep water.

DATA COLLECTED

Whitestone and Bayside. Have a few small sewers; manhole heads, in most cases, buried by street grading.

FOURTH WARD, JAMAICA

Separate system of sewers covers about 10 per cent. of whole area. Dry weather flow treated at antiquated disposal plant.

FIFTH WARD, THE ROCKAWAYS

SEPARATE SYSTEM

Far Rockaway. Sewage is pumped up from sewers to disposal plant, antiquated and inefficient.

Arverne. Outlet sewer ending on beach about half way between high and low water. Sewage also discharged into canal heading out from harbor.

Remaining Towns. No systems of sewerage yet. Sewage will require pumping as ground is but 5 feet or 6 feet above mean high water. Winter population of district 10,000, summer population 150,000.

Extent of the System The number of miles of sewers built in Queens each year, the number of catch basins built and of permits issued for connections are shown in Table XIII.

TABLE XIII
GROWTH OF SEWER SYSTEM IN QUEENS

Year	Sewer Mileage		Number of Basins		Permits For Connections
	Built During Year	Total to Date	Built During Year	Total to Date	
1897.....	....	.....	....	....	....
1898.....	....	133.000	....	1,302	....
1899.....	9.125	.....	142	....	....
1900.....	....	.....	....	....	....
1901.....	3.51	145.635	48	1,492	149
1902.....	....	.....	....	....	....
1903.....	....	.....	....	....	....
1904.....	....	.....	....	....	....
1905.....	....	.....	....	....	....
1906.....	6.64	.....	19	....	779
1907.....	8.50	.....	88	....	975
1908.....	3.90	191.*	100	1,700*	....

* The Board of Estimate report.

The following table shows the number and estimated costs of sewers authorized to be built annually in 1902 to 1908, inclusive:

Date	Number	Costs	District Shown on Drainage Maps
1902.....	16	\$45,932 50	1
1903.....	28	122,421 00	2
1904.....	24	196,870 00	2
1905.....	28	406,500 00	6
1906.....	29	648,800 00	2
1907.....	29	129,400 00	16
1908.....	20	91,600 00	12

MAINTENANCE OF THE SEWERAGE WORKS

Inspections. The inspections of sewers and basins is done by the foremen of the cleaning and other maintenance gangs. Regular systematic inspections are not made.

Cleaning. The frequency with which basins are cleaned varies from every two weeks to every two years. There are about 1,700 reported by the Board of Estimate, but no records exist of the exact number. In 1907 6,141 basins were cleaned, which corresponds to an average of over $3\frac{1}{2}$ times per year per basin. The costs are necessarily high in Queens on account of the distances to be covered. No machines or pumps are used or thought feasible to aid in cleaning basins. Steam pipes do not exhaust generally into the sewers, although a cloud of it was noticed on November 4 coming from the manholes over a sewer in Freeman avenue, between Vernon avenue and the river. This would prevent the inspection and cleaning of this particular sewer.

Street cleanings, to some extent, go into the basins. No attempt is made to enforce the ordinance against the practice. The streets in Long Island City are kept reasonably well cleaned. As snow is not cleared off, as a general thing, very little goes into the basins.

Disposal of Cleanings. The grit and other materials removed from the basins and sewers are generally dumped on vacant lots. No attempt is made to bury or cover with lime, or to treat it otherwise to prevent nuisance.

DISPOSAL OF THE SEWAGE.

TIDAL DISCHARGE

Long Island City. The sewage of the Long Island City district all discharges into East river and Newtown creek. It is stated that all the dry weather flow of sewage

is diverted from the sewers draining into Newtown creek; under the law no sewage can be discharged therein.

Ridgewood. The sewage of the Ridgewood district, which is drained by the large sewer on Myrtle avenue, with an outlet into the head of Newtown creek, is diverted into the South Fifth street sewer of Brooklyn and discharged into the East river near the Williamsburg Bridge. The storm water from this district goes into Newtown creek.

Elmhurst. The sewage of the Elmhurst district back of Long Island City, goes to a badly located disposal plant, inefficiently operated, the effluent from which discharges into a small branch of Flushing creek.

Flushing District. The sewage of Flushing, College Point and Bayside is discharged into tide water.

Jamaica. The Jamaica sewage goes to a point south of that city for treatment, and thence into Bergen creek and Jamaica bay.

DISPOSAL PLANTS

Jamaica. The Jamaica disposal plant, put in operation in 1903, is of the Powers chemical precipitation type, similar in principle to those of Brooklyn. After receiving its dose of lime and chemicals the sewage travels some 1,500 feet through the six settling channels. Sludge, amounting to about 40 tons monthly, is removed to a depression near the plant, from which it flows over on private property and causes more or less nuisance.

The effluent from the precipitation tanks, according to 1907 Board of Health report, showed putrescence in less than 12 hours.

The plant was examined by Mr. Rudolph Hering in 1908, who, from analyses of the raw and treated sewage, found that about one-third of the organic matter and two-thirds of the inorganic and suspended matters were being removed. Too little lime was being used and the use of perchloride of iron had largely been discontinued on account of cost. It was suggested that lime and copperas be used in warm weather, dispensing with chemicals in winter, as the process of purification was largely due to sedimentation. The capacity of the plant is supposed to be 1,000,000 gallons daily, but from the pump records an average of 1,500,000 gallons daily was being treated during the year of 1907. Fourteen men are reported as being employed at this plant.

Far Rockaway. The Far Rockaway chemical precipitation plant is of the Powers type and similar in design to the Jamaica plant. It was put in operation in 1896. In the summer time the plant is very much overloaded and is both antiquated and inefficient. The average amounts pumped are recorded as about 600,000 gallons daily. Lime is mixed with the entering sewage, which must traverse through four chambers having a combined length of 300 feet. The sludge is disinfected and used



A Sewer Discharging from New York City, Borough of Queens. Many New York sewers discharge their contents above low water mark



Sewer Outlet in the Harlem River. With the growth of population, rapidly increasing quantities of sewage are being discharged into the Harlem river

for filling low land near the plant. The disposal of the sludge here creates more or less nuisance and it has been recommended that a channel be dredged to the bay so that it may be removed to sea in barges. In 1907 the State Board of Health found the effluent discharged color from methylene blue in 52 hours. Undoubtedly this good showing is not the usual summer condition. Analyses made on November 30, 1904, by George A. Soper showed that the treatment was unsatisfactory. There were 40 per cent. more bacteria in the effluent than in the raw sewage, the number in the latter being 5,240,000. The imperfectly purified sewage from this plant, discharged into Jamaica bay, contaminated oysters and clams and produced a number of cases of typhoid fever. See Soper, *Medical News*, N. Y., February 11, 1905.

The following table gives data concerning the chemicals used and the number of gallons of sewage pumped during the years 1906 and 1907 at the Far Rockaway and Jamaica disposal plants.

TABLE XIV
CHEMICALS USED AT FAR ROCKAWAY AND JAMAICA DISPOSAL PLANTS

	Far Rockaway		Jamaica	
	1906	1907	1906	1907
Vitriol (H_2SO_4) pounds.....	1,600	1,680	650	635
Perchloride of iron, pounds.....	6,405	6,953	3,244	3,521
Perchloride of iron grs. per gal.....	2.1	1.7	.61	.45
Manganese, pounds.....	1,520	1,440	700	500
Manganese, grs. per gal.....	.51	.35	.13	.06
Salt, pounds.....	1,690	1,600	700	500
Salt, grs. per gal.....	.56	.39	.13	.06
Lime, barrels.....	692	827	257	249
Lime, grs. per gal.....	4.6	4.1	.96	.6
Total million gals. pumped.....	211	285	375	542
Average million gals. daily.....	.58	.78	1.03	1.48

Elmhurst. The Elmhurst plant was located at a topographically unsuitable place for the reason that this site was dedicated to the City by owners of property in the town of Elmhurst, a section perhaps 10 blocks square.

The Elmhurst plant, which has a rated capacity of 1,000,000 gallons daily was built in 1905 from the plans of Mr. Chas. Hart after the process of the International Sewage Disposal Co. of Boston. It consists of a pump, pump well, four concrete settling tanks, a flush tank and three open sand filters with a combined area of one

acre. The State Board of Health found the filters out of service at the time of two visits to the plant, the tanks only being used. The effluent customarily flows away from the plant through accidental cracks in the cement flooring. The question of payment for the plant is still under litigation. In connection with the testimony taken measurements were made of the actual amounts of sewage and of ground water flowing to the plant and there was found so much of the latter that the dilution is said to give practically sufficient purification without further treatment.

Supervision. The three disposal plants are operated by the Maintenance Department of the Bureau of Sewers under the direction of the Superintendent; to be technically and properly operated they should be under the Chief Engineer's supervision. No doubt the lack of a technical head may account for much of the adverse criticism against all of these plants.

COMPLAINTS AND NUISANCES FROM THE DISPOSAL METHODS IN USE

Whitestone. Emphatic complaints from the people of Whitestone endorsed by the Board of Health, have been made against the discharging of sewage into a small fresh water stream in the vicinity of Powells cove. A plan for the extension of the sewer into the shallow waters of the cove was not approved as a nuisance would surely be caused thereby.

Newtown Creek. While it is admitted that Newtown creek is an open sewer it is said that the pollution is due quite largely to manufacturing wastes rather than house sewage.

FUTURE PLANS OF THE LOCAL AUTHORITIES

Waterfront of Queens. Queens has relatively but a small water-frontage from which either by legal restrictions or by reason of the creating of local nuisances it is permitted to discharge raw sewage. This available shore line, covering some 21 miles, extends along the East river from Newtown creek to Berrian Island and from College Point to Whitestone Point, excluding Powells cove. The State Board of Health has ruled that the sewage going into Jamaica bay must be treated; it is thought to treat to a non-putrescible stage is sufficient. To discharge untreated sewage into Newtown creek is prohibited and the Board of Estimate and Apportionment has refused to adopt plans for discharging into Bowery bay and Flushing creek. The discharge into Powells cove now causes a nuisance. Little Neck bay is too shallow to consider any outlets there and no discharge would be tolerated off Rockaway Beach.

General Sewerage Plans. Comprehensive plans have not been made for Queens, though sadly needed by the Bureau of Sewers in order to permit properly designing the independent works of rapidly growing sections in a manner to conform to future growth and construction work for the borough in general.

Suggestions by Board of Estimate and Apportionment. The reports of the Chief Engineer of the Board of Estimate and Apportionment for 1906 and 1908 show in the following extracts and notes the general policy in his mind concerning the sewer system of Queens:

"This office has consistently urged the preparation of plans which will avoid the necessity of additional plants for sewage treatment by carrying the raw sewage to points where it can be discharged into the deep waters of the East river. In districts on the south side of Long Island, where the outlets must necessarily be in the shallow water of Jamaica bay, treatment is necessary and is required by the State Board of Health, but on the north side it is possible to secure outlets in the East river which will be unobjectionable for years to come."

Long Island City. An intercepting trunk sewer to discharge into Hell Gate at the foot of Winthrop street is suggested for the sewerage of the area between Long Island City and Flushing creek, as well as for a portion of Long Island City for which has been planned a sewer to empty into Bowery bay east of Berrian Island at the foot of Theodore street.

The Elmhurst disposal plant would be abandoned under this plan.

The Bureau of Sewers contends that this intercepting trunk sewer plan is too expensive to be carried out at the present time. While agreeing that discharging sewage into Bowery bay may possibly cause a nuisance in the future it is believed by the Bureau of Sewers that the territory drained will be developed at a much more rapid rate if not burdened with too great expense for sewerage at present, and that when more fully occupied the improvements can be more easily carried out.

Richmond Hill and Woodhaven. A separate system of sewers delivering to the Jamaica disposal plant has been authorized for a 400-acre section of Richmond Hill. A similar plan for 1,700 acres in the Woodhaven district, extending from Richmond Hill to the Brooklyn borough line has also been approved. A disposal plant was proposed at the head of Willow creek. Later developments respecting the treatment of Jamaica bay water-front indicate that it is by no means certain that any of these improvements would fit in with waterfront plans. Plans are now being made to keep down present expenditures by designing combined sewers for present needs only, discharging the dry weather flow through Stanley street in a 6-foot sewer to the Jamaica disposal plant, and bypassing the storm water flow down Panama street through a twin sewer with equivalent diameter of 12 feet. This will empty into a ditch 8 feet by 36 feet, 5,600 feet long. One of the difficult engineering features will be a syphon under the water supply aqueduct, which must be carried over the ditch on girders.

The Rockaways. The whole sewer system of the Rockaways must be reconstructed in the near future. Trunk sewers extending from end to end of the shore line, with pumping stations to lift the sewage disposal plants is the only solution proposed by the local authorities.

Jamaica Bay Improvement. One of the most important public improvements planned by the City of New York is the creation of a great harbor in Jamaica bay, the navigation interests of the city demanding greater dockage facilities than can be provided in the waters around the present harbor. The project has passed the preliminary stage and the way appears open for its execution, the Commissioner of Docks and Ferries having been directed by the Board of Estimate and Apportionment to prepare plans therefor.

It is recommended that a channel 1,500 feet wide and 30 feet deep be dredged through Rockaway inlet with a main channel following the western and northern sections of the bay for a width of 1,000 feet and a depth of 30 feet. The report of Col. John G. D. Knight, United States Corps of Engineers, under date of January 30, 1909, gives the estimated cost of deepening the Rockaway inlet and the main channels, with the necessary protection works as \$8,610,050; the cost of development as a harbor will be in addition to this.

The creation of an important harbor at Jamaica bay increases the difficulties of providing adequate sewerage and sewage disposal facilities for the portions of the Boroughs of Brooklyn and Queens having water frontage along the bay.

Recommendation—The Metropolitan Sewerage Commission recommends that immediate consideration be given to improved sewerage and sewage disposal for this district in conjunction with the elaboration of the harbor plans, so that when the latter improvements are carried out the sewerage works will be suitable for the future developments.

RICHMOND

GENERAL FEATURES AND CONDITIONS

Principal Topographical Characteristics. The Borough of Richmond includes the whole of Staten Island which has an area of 57.2 square miles. Its greatest length is 13.6 miles and greatest width 7.5 miles. It lies about 5 miles to the southwest of Manhattan and is separated from the New Jersey shore by the Arthur Kill. Its northern edge forms the southern limit of the Upper bay and bounds the Narrows, or entrance to the Upper and the Lower bays. The Arthur Kill has a minimum depth of 13 feet and minimum width of about 500 feet; the Kill von Kull has a 24-foot channel into Newark bay and a total width between piers of about 1,500 feet.

The island is kite shaped with a backbone of serpentine extending from St. George southwest about one-half the length of the island. Approximately 80 per cent. of the

whole surface of the island is covered by the terminal moraine of the continental glacier rising in hills and ridges from 200 to nearly 400 feet above the sea and composed of the typical boulder clay, soft and sandy, with rather more sand than clay. The surface is impervious and a number of small lakes are scattered over the high lands.

The drainage districts as a consequence of the topography are of various sizes extending from the shore line back to the ridge, and in general the limits are the limits of the natural watersheds of the small streams originally draining this territory. The more thickly settled portion of the island occupies a belt about a mile wide along the north and east shores from Holland Hook to Fort Wadsworth.

Distribution of Population. The population of the borough in 1905 was 72,939; the principal center being on a strip about a mile wide, more or less, extending from Fort Wadsworth to Holland Hook. The remainder of the island is rather sparsely populated with the exception of a few villages and towns; the average population for the whole borough is about 2 persons per acre.

The principal towns and villages are New Brighton, Tompkinsville, Stapleton, Rosebank, West New Brighton, Port Richmond, Mariners Harbor, Morgan Hills, Grant City, New Dorp and Tottenville.

The manufacturing interests, which are extensive, are located mainly along the shores of Kill van Kull and Arthur Kill. The shellfish interests, which are large, are principally along the south shore, between Great Kills and Tottenville. The borough is essentially a residential district. South Beach and Midland Beach are popular resorts in summer.

The Bureau of Sewers. Under the Borough President is a Commissioner of Public Works and an Assistant Commissioner of Public Works. The subordinate departments are a Bureau of Accounts, Bureau of Highways, Bureau of Engineering, Bureau of Street Cleaning, Bureau of Sewers and Bureau of Public Offices and Buildings. The Bureau of Engineering has two divisions, one of Construction and one of Topography.

The following extract from the 1907 report of the Borough President describes the operation of the organization with reference to sewers:

“The topographical engineers survey districts and plan streets; the local Board of Aldermen initiates the improvements and the Board of Estimate authorizes them. The construction engineers plan the improvements and handle their execution; the Bureau of Highways maintains the finished road surfaces; the Bureau of Sewers maintains the sewers and drains; the Bureau of Street Cleaning removes and disposes of the refuse, house and street; * * * the Bureau of Accounts handles all the different financial matters connected with these operations; and the general administration supervises the whole.”

There are about 100 technically trained men employed in the various bureaus. These men are so assigned as to keep up the work in each division without surplusage in some and insufficiency in others. Sufficient appropriations are made to pay for adequate designs, supervision and inspection of all works undertaken.

SEWERAGE WORKS

Design. The general policy now being worked out is the provision of trunk intercepting combined sewers about one-half mile apart around the island. The trunk sewers are designed with overflows for storm water at the bulkhead line, the sanitary or dry weather flow being carried out in a smaller pipe to the pierhead line. This plan has been carried out in districts Nos. 2, 6, 8, 17, 18 and 19.

Combined sewers with many frequently cleaned basins are considered best for the thickly built up portions of the borough; sanitary sewers are expected to answer in less compact districts for many years to come, as the storm water can travel on the roads and find outlets through natural drainage channels, *e. g.*, in Port Richmond and New Brighton.

The formulae used in designing the sewers are given on pages 89 and 90. The sewers are designed to take storms of the so-called second magnitude. Just how much flow the sewers would carry if a slight head was put upon them has not been considered, so that flooding due to the extraordinary storms coming once in five years may or may not occur.

A continuous automatic rain gage has been in use since September, 1902. This record shows that conditions on Staten Island are somewhat different from those found in Brooklyn by the Department of Water Supply. Velocity measurements of flow have been made in street gutters having smooth and rough pavements. From the 1908 Board of Estimate report "The determination of the elapsed time for the surface flow to reach the sewer and as required for applying the rational formulae * * * is taken to be that required to traverse the gutters with an additional allowance of five minutes."

Sewers. The older sewers, built before Staten Island became one of the boroughs of New York, were all of vitrified pipe. Each small district or town put in its own system and practically no attempt was made to care for anything but sanitary sewage. The watersheds are comparatively small and the need to carry off storm water flows other than by natural channels or the street gutters was not so necessary. The outlets of all of these sewers was at or very near the shore line, which became in time the bulkhead line.

All of the larger trunk outlet sewers are being built of reinforced concrete. A number are flattened out in order to keep the hydraulic gradient within the sewer. There is now under construction a reinforced concrete twin sewer in Canal street, Stapleton, which occupies practically the whole street.

Vitrified pipe is used for all sewers 20 inches and less in diameter, while above this size brick or concrete may be used. Concrete pipes have not been used. By the use of stone dust and screenings it has been found feasible to construct basins that are water-tight under outside pressure heads up to four feet.

Much of the new work has been carried on during the last three years, so that the system as it now exists is of very recent construction. Mention may be made here of the Tompkins avenue combined sewer in District No. 1, which has 29 drop manholes in a distance of 7,883 feet, to prevent high velocities wearing out the sewer bottom.

Catch Basins. Catch basins to divert storm water into the sewers are built at street intersections.

Ventilation. The sewers are very well ventilated, as there are a great many man-holes, all of which have perforated covers; most of the sewer outlets discharge above low tide level.

Flush Tanks. Flush tanks are employed and as a rule give good service. They are placed on sanitary sewers only. The 1908 report records the cleaning of 145 at an average cost of 61 cents each.

Outfalls. All the sewers in the borough discharge into tidewater. Such new outlet sewers as have been built since Staten Island became a borough of New York, have been so constructed that they may at some future time be connected with a large interceptor skirting the shore line and carrying its contents to various sewage disposal plants or to a tunnel leading out to sea. No definite disposal areas have been picked out and no plans have been drawn embodying any of these ideas.

The principal sewer outlets, with their respective watersheds, diameters, capacities, lengths and costs are given in Table XV.

TABLE XV
OUTLETS OF SEWERS OF RICHMOND

Street	Description	No. of Dist.	Acres in Dist.	Equivalent Diam. Outlet	Capacity Outlet c. f. p. s.	Length in Feet	Total Cost For Length Reported
Harbor road.....	Comb. with san. outlet.	19	79	4'4"	108	8,580	\$57,219.12
Union avenue.....	Comb. with san. outlet.	18	40	3'10"	67	4,761	34,776.28
Houseman avenue..	Comb. with san. outlet.	17	123	{ 6'0" 12" san. }	188	10,173	69,575.38
Church street.....	.....	9	48	2'6"	85	2,126	13,099.35
Hamilton avenue...	Comb. with san. outlet.	8	34	{ 12" san. 3' 10" }	76	5,876	37,906.61
Jay street.....	Comb. with san. outlet.	8		{ 12" san. }			
Arietta street.....	Comb.....	1	257	6'0"	265	10,130	78,046.69
Elizabeth street....	Comb. with san. outlet.	2	154	{ 6'0" 15" san. }	259	8,386	101,671.90
Canal street.....	Storm water only.....	3	1216	9'3"	895	under	construction
Water street.....	Combined.....	3		4'6" x 6'6"	461	.....	.....
Dock street.....	Combined.....	3		2'4" x 3'6"	old sewer	.....	.....
Norwood avenue...	Combined.....	4	85	3'6"	108	1,805	5,458.70
West street.....	Combined.....	5	264	{ 3'0" x 4'0" }	334	proposed	.....
Maple avenue.....	.....	5		{ 6'9"* }			
Nautilus street....	Comb. with san. outlet.	6	367	6'6"	494	5,717	95,684.41
					3,340		

*Proposed

Growth of System. The growth of the sewerage system in Richmond, year by year, is exhibited in Table XVI.

TABLE XVI
GROWTH OF SEWER SYSTEM IN RICHMOND

Year	Mileage Sewers Built each Year			Total Mileage Sewers Built to Date			Costs of Sewers Built During Year
	Sanitary	Combined	Total	Sanitary	Combined	Total	
1897.....	....	....	....	59.466	.....	73.388	
1898.....	.278	....	.278	59.744	.....	73.666	\$3,832
1899.....	.130	....	.130	59.874	.....	73.796	1,670
1900.....	.020	....	.020	59.894	13.922	73.816	2,052
1901.....	.055	.095	.150	59.949	14.017	73.966	36,205
1902.....	.031	.177	.208	59.980	14.194	74.174	54,072
1903.....	.170	.030	.200	60.150	14.224	74.374	27,164
1904.....	.085	.055	.140	60.235	14.279	74.514	19,748
1905.....	.013	.007	.020	60.248	14.286	74.534	2,702
1906.....	.024	.013	.037	60.272	14.299	74.571	31,137
1907.....	.086	.438	.524	60.358	14.737	75.095	164,094
1908.....	.272	.733	1.005	60.63	15.47	76.10	306,787

From the above table giving the mileage of sewers built and costs since 1898 it is readily seen that much work has been done in recent years, with construction costs in 1907 and 1908 in excess of anything before recorded.

MAINTENANCE OF THE SEWERAGE SYSTEM

Inspection. It is said that every basin and manhole cover in the borough is raised probably once a week throughout the year. This rigid inspection enables the Bureau to be the first to find stoppages, and, therefore, has prevented complaints. No suits for flooding have been brought for over five years. It is claimed that this inspection system is the most efficient of any in this country.

Cleaning Basins. The basins are cleaned very often and as a time saver a portable centrifugal pump driven by a five horsepower gasoline engine is used to pump out the water from the basins to the nearest sewer manhole. This very greatly increases the efficiency of the basin cleaning force.

No steam pipes exhaust into any of the sewers and no trade wastes or gases prevent the inspectors from going down into the manholes to inspect or clean the sewers.

The street cleaners do not make a practice of putting street sweepings or snow into the basins. Violations of ordinances covering these matters are reported to the Commissioner of Public Works, who puts a stop to such practices by orders to the Street Cleaning Bureau. This is one of the advantages of Richmond's centralized organization.

In 1907 there were 10,339 basins cleaned; 2.05 miles of sewers hand flushed, and 1.10 miles culverts, drains, etc., cleaned. There are but 685 basins, so that each basin was cleaned on an average of fifteen times during the year.

Disposal of Cleanings. In that territory within economical hauling distance of the New Brighton Incinerator sewer and basin cleanings are put through the furnace at a temperature of from 1,250 to 2,000 degrees Fahrenheit, with regular garbage collections. The cleanings in other parts of Richmond are hauled to public dumps, covered with lime or buried to prevent causing any nuisance. The dumping grounds are usually at a low elevation, so that the cleanings serve as fill.

DISPOSAL OF THE SEWAGE.

Tidal Discharge. All the sewage of Richmond borough is discharged into the neighboring tidal waters without treatment or purification. The policy with respect to the newer sewers has been to provide storm water overflows at the bulkhead line, and to carry the outfall for the dry weather flow out to the pierhead line.

Complaints. It is said that no complaints have been received that the sewer outlets caused a nuisance either from being open and unsightly at the end or by reason of odors arising from the discharges. Nevertheless both of these conditions occasionally occur.

Burning Sludge. It is believed that the sludge can be passed through incinerators together with ordinary garbage and that, by installing sewage and garbage disposal plants at frequent intervals around the water-front the problem can be economically solved without creating a nuisance even within thickly settled districts.

SECTION II

SEWERAGE OF THE METROPOLITAN DISTRICT IN NEW YORK STATE, EXCLUSIVE OF THE CITY OF NEW YORK

SEWERAGE OF THE BRONX VALLEY

Historical. The most important sewerage project in the New York State metropolitan district, excluding the sewerage of The City of New York, is that which is known as the Bronx valley sewer. Its purpose, as its name implies, is to pro-

vide a means of sewerage and sewage disposal for the towns in the valley of the Bronx river north of the limits of the Borough of The Bronx of The City of New York.

The matter of constructing an outlet sewer for this district was under consideration for several years before reaching definite shape. It was investigated carefully and reported upon in 1895 by the late J. J. R. Croes, Past President, Am. Soc. C. E., and by J. J. Fairchild, C. E., who recommended the construction of a trunk sewer from the upper limits of White Plains to a point some miles below Mount Vernon in the Bronx valley and thence easterly across the marshes to Long Island Sound. This plan was defeated and the matter was dropped until the commission known officially as the Bronx Valley Sewerage Commission, appointed in 1904, took it up. The Commission's work was made effective by Chapter 646 of the Laws of 1905 of the State of New York which provided for "the construction and maintenance of a sanitary trunk sewer in the County of Westchester" and provided "means for the payment thereof."

This act is specific in defining the area within the different townships included in the districts to be sewered, in establishing the route of the sewer and providing that the sewage shall be discharged into the Hudson river.

Trunk Sewer. The plans provided for the construction of a concrete trunk sewer of circular cross section some 14 miles in length extending down the valley of the Bronx river from the northern limits of White Plains to within 300 feet of the boundary line between The Bronx and Westchester County, turning thence west, parallel to this boundary line and passing under the intervening land in a tunnel to the Hudson river where it is to terminate in two lines of 54-inch cast iron pipe extending from the portal of the tunnel to a point in the river 500 feet from the shore and about 40 feet below the surface of the river.

At its upper end, above White Plains, it is to be 3 feet 4 inches and, at its lower end, below Mt. Vernon, 6 feet in diameter. The tunnel section is to have a diameter of 6 feet 6 inches at Washingtonville, the point of deflection, increasing to 8 feet at the Hudson river end, 200 feet east of the tracks of the New York Central and Hudson River Railroad.

The sewer is intended to take only house and factory sewage, to the exclusion of storm water, and is to intercept and convey to the Hudson river the sewage of White Plains, Scarsdale, Tuckahoe, Bronxville and parts of Mt. Vernon and Yonkers, as well as the sewage due to natural increase in population in these towns and the development of new territory in the vicinity, for many years. No provision was made in the plans for the purification of the sewage, or for screening it, or reducing the quantity of solids in suspension by settlement; it is now stated that a partial purification, by screening and subsidence is contemplated.

Topography. The valley of the river is a narrow strip about 25 miles long having a width of $1\frac{1}{2}$ to $2\frac{1}{2}$ miles, and lying in Westchester County and the Borough of The Bronx, with its axis parallel to the Hudson river. The northerly 18 miles of the valley is in Westchester County. The watershed in Westchester County is about 48 square miles, of which 12 square miles have been appropriated by The City of New York and $4\frac{1}{2}$ square miles by Yonkers for their respective water supplies. The use by these cities of all but the surplus rainfall from this appropriated territory reduces the summer flow of the stream at the Westchester County line to not over two cubic feet per second, a quantity too small to permit the discharge of the sewage of the towns on the watershed therein without causing great offensiveness. The river is a tidal estuary as far as the tannery dam at West Farms.

Towns within the District. The estimated population of the villages and towns within the district was (1909) approximately:

White Plains.....	12,800
Hartsdale	1,700
Scarsdale	1,800
Yonkers	5,600
Tuckahoe	2,300
Bronxville	1,500
Mt. Vernon.....	4,300
	<hr/>
	30,000
	<hr/>

White Plains is completely sewered, the sewage passing through a plant intended for its purification by chemical precipitation, with disinfection of the sludge. Hartsdale has no sewers, nor has Scarsdale or Yonkers Park. Tuckahoe has sewers and a small purification plant put in operation September 1st, 1907, the effluent from which discharges into the Bronx. Bronxville also has a sewer system and a small plant for treating the sewage. Mt. Vernon is completely sewered; 25,000 people, or 95 per cent. of the total population is served by the public sewer system discharging through three separate outlets into the Hutchinson canal, or Hutchinson river, which flows into the canal. About 85 per cent. of the sewage of the city is discharged into the main outlet sewer which empties into the upper end of the canal at the foot of Fulton avenue.

The sewage from possibly 4,000 to 5,000 people in Mt. Vernon will be diverted to the Bronx valley sewer. This population resides in a district from which the sewage is now pumped across the divide for discharge into Eastchester creek.

Over 50 per cent. of the population which the Bronx valley sewer is designed to serve resides in White Plains, Tuckahoe and Bronxville, the sewage of which is now subjected to partial, although not satisfactory purification.

Opposition. After the publication of the plans for the construction of this sewer application was made by the Bronx Valley Sewerage Commission to the State Board of Health for permission to construct the sewer. In order to become acquainted with the nature of the proposed works the Metropolitan Sewerage Commission, in August, 1906, examined the plans on file at the office of the Commission at White Plains. On November 30th, 1906, word was received from the State Department of Health that a hearing would be held on the Bronx Valley Sewerage Commissioners' application on December 7th, 1906, at the office of the Commissioner of Health in Albany. Two members of the Metropolitan Sewerage Commission, as well as several representatives of other interests were present. Active opposition was manifested against the project. Following this meeting the Merchants Association of New York through Mr. Edward Hatch, Jr., Chairman of the Committee on Pollution of Water of that association, addressed a protest to the Secretary of War against the construction of the Bronx valley sewer. The question as to the authority of the State Department of Health and the State Engineer and Surveyor to attach their approval to the plans for the sewer as then drawn, was submitted by the Commissioner of Health to the Attorney General on December 10th for an opinion. Under date of December 13th, 1906, Assistant Attorney General Danforth replied that in his opinion "the State Commissioner of Health can not travel outside of the provisions of this act (Chapter 646 of the Laws of 1905) and impose a condition not provided for in the act itself. It is the positive mandate of the Legislature that a sewer of the character described in the act, constructed for the purpose specified in the act, on the route mentioned therein and terminating into the waters of the Hudson river shall be constructed, and the province of the State Commissioner of Health in affixing his official approval to the map and plans thereof, is to certify that such a sewer will accomplish the purposes stated in the act."

Approval of Plans. Acting in accordance with this decision which passed upon other questions relating to the construction of the sewer the Commissioner of Health on December 31st, 1906, returned to the Bronx Valley Sewerage Commission at White Plains the plans for the Bronx valley sewer with his approval attached thereto.

Various protests have been made since the filing of this decision, but to no avail, as the Bronx Valley Sewerage Commission has proceeded with the construction of the sewer in accordance with the plans which were approved by the Commissioner of Health.

Outfall. In the plans for the discharge of the sewage into the Hudson river at Mt. St. Vincent, the outfall sewer instead of terminating at the bulkhead line and discharging at approximately tide level as is the custom along this section of the Hudson river shore, will be carried out to the pierhead line and be discharged through two

outfall sewers at an elevation some 35 feet below tide level, by which it is hoped to obtain complete diffusion of the sewage, its rapid digestion by the river water and the prevention of visual pollution along the river shore.

It is estimated that a population of 680,000 will be tributary to the sewer some years hence.

The work of construction is now (1909) under way at various points in the Bronx valley and the tunnel to the Hudson river has been started.

The population sewered in the Bronx valley district in the year 1908 is estimated to have been 32,700 and the quantity of sewage now produced is estimated to be 2,000,000 gallons per day. By the time the outfall and the sewer are completed the sewage discharge will probably amount to 3,000,000 gallons per day.

SEWERAGE OF WHITE PLAINS

Several of the towns in the valley of the Bronx river in Westchester County are provided with plants for the purification, or at least partial purification, of the sewage. The first of these to be constructed was the plant at White Plains.

Sewers. The construction of a system of sewerage works for the reception of sewage only to the exclusion of storm water was commenced in 1893. At the present time there are some 30 miles of pipe from 8 to 24 inches in diameter and 50 flush tanks. An ejector station at Westchester avenue and North street lifts from 100,000 to 300,000 gallons of sewage per day to a higher level sewer from that portion of the city which is too low to discharge by gravity to the sewage purification plant.

Sewage Flow. The population connected with the system of sewers is about 12,000. No manufacturing wastes enter the sewers, but there is a considerable amount of leakage into them of ground water. The average flow of sewage is possibly a little less than a million gallons per day.

Purification Works. The sewage flows to a sewage purification plant built under the patents of J. J. Powers. As it enters the works the sewage receives a stream of milk of lime, and another of a solution of perchloride of iron, flowing thence 150 to 200 feet through mixing tanks and passing through a screen of $\frac{1}{2}$ -inch mesh, and under two baffle boards to a siphon chamber. From the siphon chamber it passes into a sedimentation basin 45 feet long and 24 feet wide, from which it again siphons into a well and passes through an effluent pipe some 2,000 feet long to the Bronx river. The bottom of the river is usually covered with sediment deposited from the partially purified effluent. Five to six barrels of lime are used at the plant daily. The lime solution is agitated by pumping the water through a perforated pipe in the bottom of the mixing troughs. The iron solution is mixed in an 1,800-gallon iron vat, the quantity used

daily frequently reaching a carboy. The iron solution is agitated by blowing compressed air through it.

The sludge is pumped from the tanks weekly upon adjacent sludge beds of which there are two having a combined area of 3,600 square feet. Sludge accumulates to a depth of three or four inches at each cleaning, and is left on the beds for about a week, or until dry enough to be winrowed to hasten the drying. Some 35 cubic yards of material are removed at each cleaning. About 24 hours previous to cleaning the sedimentation chamber it is the practice to treat the sludge with chlorine prepared by mixing oxide of manganese, salt and sulphuric acid. The mixture is made in a lead lined iron tank having a gauge indicating the pressure in the generator; sufficient acid is added to the salt and oxide of manganese to produce the required pressure, on reaching which the gas is fed to the tanks to be cleaned through 2-inch lead pipes perforated with $\frac{1}{4}$ -inch holes 12 inches apart and fastened to the sides of the sedimentation chamber six inches above the bottom.

One of the attendants in charge of the work maintains on one of the sludge deposits a small garden in which vegetables are successfully cultivated notwithstanding the visible presence of lime and many particles of the more indestructible ingredients of sewage.

The annual cost of operating the plant in 1907, including the cost of operating the ejector at Westchester avenue and North street, is given as about \$8,700.

Defects. The sewage disposal plant at White Plains has for a number of years failed to purify the sewage sufficiently to prevent the objectionable pollution of the Bronx river. The late J. J. R. Croes gave an opinion in December, 1905, after an investigation of the plant and the character of the effluent, that "the interests to public health demand that the village of White Plains should be required to take steps at once to improve the character of the effluent either by more efficient management or the substitution of another system." In March, 1906, it was again inspected and reported upon by Mr. E. T. King, Inspecting Engineer of Water Supply of the State Department of Health, and in October of the same year, by Mr. Theo. Horton, Consulting Engineer of the State Department of Health, and on September 27th, 1907, by Mr. H. B. Cleveland, Assistant Engineer, State Department of Health, and again on October 28th, 1907, by Mr. Theo. Horton. All these examinations indicated that the purification at the White Plains sewage disposal plant, from lack of proper management, mainly in overworking the plant, was inefficient; and that decomposing deposits along the bottom and shore of the stream, resulting from this inefficient operation, produced offensive odors amounting to a public nuisance to the residents of Hartsdale, Scarsdale and other villages residing along and in the vicinity of the river below

these works. These latter investigations were made on the complaints of the citizens of the towns down the valley below White Plains.

Having in mind the probability of the ultimate construction of the Bronx valley sewer the authorities of White Plains have resisted making further investments for changes and improvements of the sewerage works. When the Bronx valley sewer is completed the sewage of White Plains will be discharged into the Hudson river.

SEWERAGE OF TUCKAHOE

Sewers. A system of sewers, for house sewage only, and a small purification plant were put in operation in Tuckahoe about September 1st, 1907. Tuckahoe which has a population of 2,000 is situated a mile north of Bronxville. The sewerage system includes 23,000 feet of pipe ranging from 8 to 15 inches in diameter, a settling tank with a maximum daily capacity of 226,000 gallons, and two aerating beds. Sewage was first allowed to flow into the sewers on June 1st, 1907. The cost of the sewers was \$39,000 and the cost of the settling tank and contact beds \$10,000 including the cost of engineering.

Purification Works. The sewage enters one of the two grit chambers 5 feet wide, 15 feet long and about 4 feet deep from which it enters a shallow semi-circular chamber through which it passes to pipes leading to one of the five settling chambers. These chambers are baffled in a manner to cause the sewage to descend to the bottom, then over a concrete weir and concrete surface from which it passes to two openings in the chamber wall discharging below the sewage surface in the main channel extending along the entrance to the two aeration beds. The tank effluent may be turned upon either or both of the beds. The aeration beds are 100 feet square and the crushed marble varies in depth from nine inches in the inlet end to six inches in the outlet end. The stones average about two inches in diameter. Three brick baffles have been placed in the aeration beds to retard the flow of the sewage. From the beds the sewer enters an effluent channel through which it flows into the Bronx river about 30 feet distant. At the present time the plant apparently is operated without any attention, and as a rule the sewage passes from the settling tanks direct to the Bronx river.

Complaints. Complaint has been made in regard to the condition of this plant, although the examination made in September, 1907, by the State Department of Health seems to indicate that the plant was capable of producing satisfactory results if properly operated.

SEWERAGE OF BRONXVILLE

Sewers. The sewerage system of Bronxville comprises a little less than six miles of pipe lines to which 160 connections, including those of two or three large hotels, have been made. The sewage flows to a well 12 feet square and 15 feet deep from which it is pumped to settling chambers by electrically driven pumps in duplicate.

Purification Works. From the pumps the sewage enters a grit chamber 12 feet wide, 20 feet long and 10 feet deep, across which is placed a vertical screen having one-half inch rods placed one inch, center to center. From the grit chamber the sewage enters the settling chamber in which it flows a distance of 40 feet, returning parallel to itself to a dosing chamber. From this chamber 250 to 300 feet of 10-inch outfall pipe leads the settled sewage to the Bronx river. A sludge pipe is provided for conducting the sludge to neighboring low land. No storm water enters the sewers. In 1908 about 1,200 persons were residing in Bronxville.

SEWERAGE OF MT. VERNON, PELHAM AND PELHAM MANOR

Pollution of Hutchinson River. Hutchinson river, in Westchester County, has, for a number of years, been grossly polluted with the sewage of Mt. Vernon, Pelham Manor and North Pelham, and numerous complaints have been made to the State Board of Health to cause the nuisance to be abated.

Mt. Vernon has had numerous examinations and reports made for sewerage and sewage disposal, but has deferred the adoption of these for one reason or another until in 1909.

Sewers of Mt. Vernon. The city is provided with a complete system of sewers, and about 28,000 of its 30,000 population (1908), are served with the system which, prior to its interception, discharged through three separate outlets into Hutchinson river. Eighty-five per cent. of the entire sewage of the city is taken to the outfall near the foot of Fulton avenue for purification.

Sewers of Pelham. The Village of Pelham, lying on the east side of the Hutchinson river, opposite Mt. Vernon, has a population of 300 or 400 who are served by the sewer system.

Sewers of Pelham Manor. Pelham Manor has a population of 650 and practically every house in the village is connected with the sewer system. At North Pelham a small amount of sewage is discharged into the river from a few houses; no sewer system has been constructed in this village.

Mt. Vernon Purification Works. It is estimated that somewhat more than 2,000,000 gallons of sewage per day originates in this group of municipalities, 1,800,000 gallons per day being the estimated quantity that will be delivered to the Mt. Vernon sewage

purification works. The process of purification adopted includes settlement and subsidence in covered settling basins, filtration through covered sprinkling filters and final settlement of the effluent in open basins. The effluent is to be discharged into a small tidal tributary of Hutchinson river at a point about three miles from the head of Eastchester bay, one of the most indented of the many long narrow tidal arms of the Sound in this vicinity.

Provisions are made for the prevention of the escaping odors from the purification works by connecting the settling basins and sprinkling filters with two tall ventilating towers intended to contain beds of oxide of iron through which the gases and vapors given off in the process of purifying the sewage may be passed to become neutralized. The works are practically complete but are not yet in operation.

SEWERAGE OF NEW ROCHELLE

Sewers. The sewerage system of New Rochelle contains upwards of 55 miles of sewers, but only the sewage of about one-third of the city on the side adjoining the town of Pelham and approximating 700,000 gallons per day for a population of 7,000 people goes to the purification plant situated at the foot of Morgan street. The effluent is discharged into Long Island Sound opposite to Glen Island, about 5,100 feet from the plant. The purification works were put in operation in the fall of 1898.

Purification Works. As the sewage enters it first passes through a screen with bars spaced one-half inch apart, thence through a baffle chamber 30 feet long and 2 feet wide, at the entrance to which the lime and copperas are introduced and subsequently mixed through the sewage by the agitation caused in passing around the baffles. From the mixing channel the sewage flows through a conduit into one of five sedimentation tanks, each 66 feet long and 22 feet wide. From these five tanks it passes into an effluent pipe and out into the Sound.

The sludge from the sedimentation tanks is drained into a cistern 12 feet in diameter in front of the building, from which it is pumped to three sludge beds each having a total length of 71 feet and a width of 25.5 feet, the three having a combined area of 1/10 acre. Around the inside of each bed and two feet below the top of the exterior walls is built a concrete shelf two feet wide, and within the area enclosed by this shelf there are 24 concrete piers two feet high with their tops on the same level as the 2-foot concrete shelf. The filtering materials in the sludge beds consist of six inches of cinders on top of 18 inches of broken stone. The liquid pumped with the sludge filters down through the cinders and enters the 3-inch underdrain tiles leading to the two sludge wells at the center of each bed. The six sludge wells are connected by a pipe and discharge into a manhole near the sedimentation chamber from whence the filtrate flows into the effluent pipe through a total length of about 200 feet of 12-

inch pipe. When the sludge on the sludge beds is dry enough to handle it is collected in piles and wheeled to a point about 150 feet distant. The total amount of sludge collected annually averages 1,240 cubic yards, or about 17 cubic yards at each cleaning. The sedimentation tanks are cleaned every five or six days, and the sludge from one of the three beds at the same time.

Annual operating expenses.

Fuel	\$78 00
Engineer and 2 laborers.....	2,860 00
45 tons copperas.....	720 00
400 lbs. lime daily at \$16 per ton.....	1,168 00
Chloride of lime, 400 tons at 45 cents per ton.....	180 00
	<hr/>
	\$4,806 00
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Cost of the plant, as estimated by the New York State Board of Health, was \$3,194.

SECTION III

SEWERAGE OF THE NEW JERSEY METROPOLITAN DISTRICT

GENERAL FEATURES AND CONDITIONS

Principal Characteristics of the District. Within the boundaries of the New Jersey part of the metropolitan district, lie several important centers of population. Some of these are situated upon relatively small bodies of water, and the discharge therein of sewage and manufacturing wastes has led to co-operative efforts to correct present and prevent future nuisances.

Among the efforts made may be mentioned:

- a. The Union outlet sewer, constructed under an agreement entered into between Montclair, Orange, Bloomfield and Glen Ridge for the discharge of the sewage of these communities into the Passaic river near the upper end of Newark.
- b. The Joint outlet sewer, so-called, which diverts the sewage of South Orange, Vailsburg, Irvington, and a portion of Newark to the Kill van Kull at Elizabeth.
- c. The proposed Passaic valley sewer.

Several of the cities in the district have investigated methods and constructed works for disposing of their sewage, among these being East Orange, where a purification plant was built and operated for a number of years, but put out of service in 1896 when arrangements were made to discharge into the Newark system, Summit, N. J., which had a purification plant in use until the joint outlet sewer was constructed, and Newark, where extensive intercepting sewers have been built leading to a pumping station from which the sewage is pumped out to Newark bay. Several reports have been made on the disposal of Paterson's sewage independently of the other communities in the Passaic valley; in Elizabeth it has been necessary to construct in-

terceptors and a pumping station to deliver the city's sewage into the Joint outlet and relieve the intolerable condition of the Elizabeth river.

Cranford and Rahway have also joint interest in an outlet sewer discharging into the river below Rahway.

Newark bay, which lies parallel to and is separated from Upper New York bay by the Bayonne peninsula, receives at its head the waters of the Passaic and Hackensack rivers. All the sewage and liquid manufacturing wastes from the communities in the watersheds of these two streams find their way ultimately into the bay, and thence into the ocean through Kill van Kull and the Arthur Kill. It is estimated that about 83 per cent. of the discharge from Newark bay goes to sea through the Kill van Kull and Narrows, and about 17 per cent through Arthur Kill. Newark bay is shallow and broad, which is one of the factors that may have prevented its becoming exceedingly offensive. Its shallowness and great area insure the replacement of a large percentage of its total volume during each tide, and the consequent extensive diffusion of the sewage through the water.

The population of the entire area within the limits of the New Jersey metropolitan district in 1905 was 1,203,387; the population of the cities and towns of over 25,000 population was 910,764, and of the small villages and rural districts, 292,623. Two-thirds of the population of the district was centered in Newark, Jersey City and Paterson.

SEWERAGE OF NEWARK, N. J.

GENERAL FEATURES AND CONDITIONS

Newark with a population in 1905 of 283,289 is the largest city in the metropolitan district in New Jersey, and is situated on the west side of the Passaic river just north of Elizabeth, east of the Oranges and south of Belleville, from which it is separated by Second river. From the Market street Station, Newark, to City Hall in Manhattan in a straight line is 8.5 miles.

That portion of Newark west of the Passaic river and Broad street, about 14 square miles in extent, is characterized by a line of hills parallel with the river. To the east and south of Broad street lie some six square miles of meadow land but a few feet above tide level. The summits of the hills in Newark rise from about 170 feet in the Riverside district to 235 feet above sea level in the West Park district. Rock outcrops do not interfere to any extent with the construction of sewers, probably less than 10 per cent. of the trenches having required blasting. Quicksand exists to a large extent in the lower levels and water bearing drift in many places.

Drainage Areas. The natural drainage areas of the northern portion of the city empty into the Passaic river, Second river and Branch brook; the southern portion into the Meadows and the western or Vailsburg section into two small creeks flowing south

into the Elizabeth river. The storm water drainage in most cases follows quite closely the natural routes.

Board of Street and Water Commissioners. A board, known as The Board of Street and Water Commissioners has charge of all public works in Newark. Reporting to the board is a Chief Engineer under whom are the engineers in charge of the design and construction of structures relating to water, streets, sewers and lighting, and a general Superintendent of Works who has charge of maintenance of streets, sewers and lights. One of the assistants to the Chief Engineer has charge, as one of his duties, of the correlation of one department with another, and the adjustment of differences which may arise with respect to conflicts of authority.

Department of Sewers. The engineer in charge of the department of sewers and drainage has under him a field and office force of eight trained engineers and three helpers; and in the house sewer connection department one engineer and various clerks. The engineers are all under State Civil Service regulation. Fifteen inspectors for construction work are permanently on the list, but are paid by the day when work is being carried on.

Department of Works. Under the General Superintendent of Works is a superintendent of sewers, appointed under Civil Service regulations. The foremen act as inspectors and are assigned to certain subdivisions of territory which they go over regularly making inspections and cleaning basins and sewers.

SEWERAGE WORKS

Design. The original sewerage of Newark was on the combined system but since the construction of the interceptor and pumping station in 1887 house drainage and ground water have been separated from the storm water over an ever increasing portion of the city. In 1908 there were 57.7 miles of house drainage sewers, 5 miles of drains for storm water only and 200 miles of combined sewers. The necessity for the disposal of house sewage at some future time, either through the Passaic valley sewer or through a local interceptor, requires that separate systems be used as extensively as possible.

For calculating the quantity of water expected to reach the sewers the formula deduced by Rudolph Hering, C. E., from gaugings of sewers in The City of New York in 1888 has been used. This is:

$$Q = C R A^{.85} \times S^{.27}$$

For Newark conditions

$$C = 1.00 \text{ in suburbs}$$

$$1.25 \text{ in half built up portions}$$

$$1.50 \text{ in down town districts}$$

$$R = \text{Rainfall intensity, in inches per hour.}$$

$$A = \text{Area in acres.}$$

$$S = \text{Slope in feet per 1000.}$$

$$Q = \text{Cubic feet per second of water expected to reach the sewers.}$$

The sewers designed by this formula have been found to take all but the very heaviest of storms. Various allowances have been made for the capacities of the house drainage sewers. In making a recalculation of the capacity of the main interceptor in 1893 it was assumed that the population would be 90 persons per acre using 75 gallons of water per diem each. Two-thirds of this quantity was to be carried off by the sewers in eight hours. For the East Branch sewer a population of 100 per acre was assumed, using 75 gallons of water per day, the sewer to run one-half full and to take two-thirds the flow off in eight hours. Later separate systems have been built using a population of 60 and even as low as 30 per acre.

An allowance for the leakage of 30,000 gallons of ground water into the sewers per day per mile of sewer is customary in designing sewers. Gaugings of the Union outlet sewer which drains Orange, Montclair, Glen Ridge, and Bloomfield, indicated to the consulting engineers of the Passaic Valley Sewage Commission that the average leakage would be about 350,000 gallons per square mile per day for the area between the mountain and the river. Provision was made at one time, prior to 1900, for the entrance of ground water into the combined sewers by laying several courses of brick in the bottom of the sewers without mortar joints.

The carrying capacity of the sewers is calculated from Kutter's formula using $n = .013$ for pipes and $.015$ for brick and concrete sewers.

All concrete sewers have inverts lined with vitrified brick so that the same coefficient is used for both brick and concrete sewers.

Velocities. It is the intention wherever possible to have the velocity in the sewers at least three feet per second.

Materials. Practically all of the older sewers above 24 inches in size have been constructed of brick. Experience with vitrified pipe of larger sizes than 24 inches diameter has not always been satisfactory in Newark. Recently reinforced concrete has been used both in place and for pipes made on the bank. In 1908 about one-third of total mileage of public sewers was either brick or concrete. A note of replacing a brick sewer in Nutria street built over 40 years ago says that it "was found to be in such dangerous condition that it was torn out and replaced by an 18-inch pipe."

Outlets. In general the elevation of the inverts of the various outlets is at low water. A few are above or below but none are above high water. It is probable that at times of high water the flow in the Jackson street and the City Dock sewers backs up half a mile or more.

Ventilation. The manhole covers are perforated and a circulation of air from manhole to manhole provided in this way.

Basin Design. Standard forms of manholes and catch basins are in general adhered to; but there are a few basins much shallower than the standard, and also a few have been built of concrete blocks and of reinforced concrete. The standard brick manhole is considered the cheapest in most cases. It is not thought practicable to eliminate the basins from much of the territory, particularly on those sewers which do not have good grades.

Flush Tanks. Flush tanks are used on the separate systems; 103 are reported as being in use in 1908.

Principal Sewers. The earlier sewers were built of pipe and brick with little regard to requirements as to size; in most cases they were made too large. Instances have been noted of the same size and grade being used from the outlet to a dead end where there was no possible chance for any further development. The drainage areas and sizes of the various Newark sewers are given in Table XVII.

TABLE XVII
DRAINAGE AREAS OF NEWARK SEWERS

	Acres	Size of Outlet	Material	Shape
Verona avenue.....	687	5'3" x 6'0"	Brick.....	Horse shoe
Delaware avenue.....	90 (not built)	.....	.....	.....
Herbert place.....	255	3'6" x 4'0"	Brick.....	Horse shoe
Third avenue.....	13	15"	Pipe.....	Circular
Fourth avenue.....	190	4'0" x 4'0"	Brick.....	Horse shoe
Clark street.....	39	3'0"	Brick.....	Circular
Millbrook.....	1,762	Two-6'9" x 9'3"	.....	Twin Horse shoe
Orange street.....	13	2'0" x 3'0"	.....	.....
Bridge street.....	12	15"	Pipe.....	.....
Rector street.....	132	5'0" x 6'0"	Brick.....	Horse shoe
Central relief.....	302	6'0" x 6'0"	.....	Horse shoe
City dock.....	354	5'6" x 6'6"	.....	Horse shoe
Jackson street.....	84	4'10" x 5'3"	.....	Horse shoe
Polk street.....	188	7'0" x 8'0"	.....	Ellipse on its side
Freeman street.....	143	4'0"	.....	Circular
Brown street.....	92	24"	Pipe.....	.....
East branch (N. of St. Charles street) ..	256	3'0" x 4'6"	Brick and concrete.	.....
Interceptor (excl. of above)	3,342	6'6"	Brick.....	Built in 1887

Of the foregoing the Millbrook twin outlet (each 6 feet 9 inches by 9 feet 3 inches) sewer at the foot of Clay street drains an area of 1,762 acres in the Roseville district and also relieves the Fourth avenue sewer.

The Central relief sewer, emptying at the foot of Saybrooke place was built to relieve the Rector avenue sewer which was overtaxed at its outlet during heavy storms.

The City Dock sewer, 5 feet 6 inches by 6 feet 6 inches, drains 354 acres in the heart of the city.

The house sewage from about one-third of the whole city discharges through the intercepting sewer into Newark bay at the foot of Bay avenue, the storm water outlet for this southern territory being into Peddie street canal and the meadows.

Interceptor. An intercepting sewer was built in 1887 to take care of the house sewage from a section in the southern portion of the city. Its capacity is stated to be 70,000,000 gallons daily, but the pumping capacity is only 30 million gallons daily. The sewer was obliged to take the house drainage and one-quarter-inch to three-eighths-inch of rainfall per 24 hours from about 7,400 acres. About 3,600 acres, or less than half of this area, is now connected. Pumping records show a great increase of flow during storms so that a good deal of surface drainage or ground water must find its way into the sewer. A yearly fluctuation is noted, but this is explained in part by the correction for slip being calculated uniformly at 8 per cent., without regard to the condition of the pumps. Just why there should be so much daily variation is not known although it is possible to shut down sewer gates controlling the discharge into the Peddie street canal and divert much or little to the interceptor. The average, maximum and minimum pumpage rates per day as measured by the plunger displacement together with other pumping station data are given in Table XVIII.

TABLE XVIII
PUMPING STATION DATA, NEWARK, N. J.

Year	Pumpage in million gallons daily				Total annual cost for pumping station
	Average	Maximum	Minimum	Coal consumed lbs.	
1888.....	7.6				
1889.....	6.7				
1890.....	9.7				
1891.....	7.8				
1892.....	8.5				
1893.....	9.6				
1894.....	10.1	19.5	5.0		
1895.....	10.3	20.1	4.0	998,852	\$10,889.77
1896.....	9.8				
1897.....	10.8				
1898.....	13.3				
1899.....	12.5				
1900.....	13.1	26.7	6.6	1,430,288	
1901.....	12.8	30.4	4.7	1,470,899	
1902.....	13.0	31.4	5.0	1,495,604	
1903.....	12.9	31.9	5.6	1,697,331	12,458.06 (Est.)
1904.....	13.3				
1905.....	13.6				
1906.....	13.2	31.6	2.6	1,672,992	17,301.73
1907.....	12.4	23.5	4.3	1,691,993	12,961.29
1908.....	13.1	30.3	5.7	1,670,637	13,884.51

East Branch Intercepting Sewer. The so-called east branch of the intercepting sewer was part of the project reported upon by Mr. Rudolph Hering in 1895. The alignment is substantially the same as recommended by Mr. Alphonse Fteley in 1884. At the present time the east branch sewer has been practically completed; it drains an area of 256 acres south of the Pennsylvania railroad and east to the Morris canal. It joins the old intercepting sewer about 2,000 feet from the pumping station.

East Orange Outlet Sewer. The East Orange outlet sewer delivers house sewage into the Mill brook sewer at Newbold avenue in Newark from practically the whole of East Orange a territory of about four square miles.

Vailsburg Sewers. The entire area of the Vailsburg section, containing 806 acres, and of about 265 acres in Newark, lying between Thirteenth avenue and Lyons avenue and approximately as far east as South Fourteenth street, discharges through the Joint outlet sewer. This sewer is under the control of a separate commission which has charge of its maintenance; Newark pays for her share in the maintenance expense \$1,200 annually. Some sections of this sewer are at times overcharged and great care, therefore, must be taken to exclude surface and roof water from the main line and branches.

Relief Sewers. Various relief sewers have been built from time to time as troubles from storm water floods in closely built up sections have appeared. The Adams street sewer project was one of these, house sewage only going to the interceptor therefrom, the storm flow being diverted to Dead creek.

Meadowbrook Sewer System. Separate systems have been provided for the house drainage and storm water run off in the valley lying west of Roseville avenue and extending from Springdale avenue to the Old Bloomfield road. The surface water system extends south as far as Park avenue. The house drainage system extends both north and south of Bloomfield avenue and delivers to a pumping station at North Sixth street near the old Bloomfield road from which it is to be pumped into the Forest Hill system.

Passaic Interceptor. In 1884 Mr. Alphonse Fteley proposed an interceptor to skirt the Passaic and take house drainage to the present interceptor through a branch on Sanford street. This scheme is still feasible and might be put through except for the possibility of the Passaic valley sewer being constructed.

Sewage Flow. Newark consumes about 35,000,000 gallons of water daily with an estimated population of 311,000, or 114 gallons per capita per day. In 1905 it was estimated that the quantity of sewage discharged through the 41,907 sewer connections was 46,500,000 gallons daily.

Growth of the System. The mileage of sewers, number of basins and cost of sewers built during various years are given in Table XIX. It is to be noted that the mileage constructed is diminishing rather than increasing. The city of Newark is practically covered by the present sewer system and very little if any new systems, at least of any magnitude, are called for. Practically all of the outlets are of sufficient size now to care for the ultimate development of the city.

TABLE XIX

GROWTH OF SEWER SYSTEM IN NEWARK

Year	Milage of Sewers		No. of Basins		Flush tanks, Total	Total cost (public sewers only)
	Built during year	Total	Built during year	Total		
1894.....	....	105.87	....	2,165	....
1895.....	13.20	128.07	133	2,298	22	
1896.....	....	.....	....	....	....
1897.....	....	.....	....	....	....
1898.....	....	.....	....	....	....
1899.....	....	162.30	....	2,579	39	\$3,278,827 82
1900.....	15.90	178.20	155	2,734	49	3,486,594 39
1901.....	5.35	183.55	65	2,799	49	3,631,164 25
1902.....	3.54	187.09	63	2,862	49	3,721,324 09
1903.....	11.60	198.69	109†	2,964†	51	3,829,914 98
1904.....	13.05	211.74	42	3,056	....
1905.....	10.32	.....	....	....	....
	10.28*	232.36¶	100‡	3,152‡	93	4,300,636 97
1906.....	10.46	242.82	23	3,225	93	4,451,257 25
1907.....	10.46	253.30	26	3,251	100	4,734,910 02
1908.....	9.34	262.65	96	3,347	103	4,916,125 78
1909.....	5.80	268.45	....	....	....

*Vailsburg added this year.

†4 basins abandoned, 3 replaced, 3 already in.

‡Probably 4 abandoned.

¶Error 0.02 mile.

The sewer outlets of Newark are considered adequate to drain the territory allotted to them in all cases excepting the City Dock, 5 feet 6 inches by 6 feet 6 inches, Freeman street, 4 feet, and Brown street, 24-inch sewers. There are, however, certain sections of the city, back from the outlets, where relief sewers are needed to prevent flooding during heavy storms.

On the whole, Newark appears to be very completely provided with sewers. The policy of laying sewers and house connections ahead of paving has been inaugurated. An ordinance prohibits the use of cesspools after sewers are provided so that there are not many cesspools left. The annexation of Belleville to the north is now contemplated. This area is not sewered at all and will probably require separate sewers.

MAINTENANCE OF THE SEWERAGE SYSTEM

Cleaning. In the business section of the city the department is able to clean all catch basins about every two weeks, but in the outlying districts perhaps not more than once or twice per year. In 1908, when there were 3,349 catch basins, 4,732 were reported as cleaned; each was, therefore, cleaned on the average 14 times per year; men are specially detailed to investigate and remedy all causes of complaint.

Disposal of Cleanings. The materials in the basins are said to be not generally putrefactive and are disposed of on public dumps approved by the Board of Health. These dumps are usually on meadow land far removed from houses. No special provision for disinfecting, covering or other treatment is made.

Steam in Sewers. Connecting steam exhaust pipes to the sewers is prohibited by ordinance and is not done to any extent.

Street Cleaning. Newark takes great pride in clean streets, but the sweepings are not allowed to be pushed into the catch basins; the rule is observed rigidly, although occasionally a limited amount of snow is crowded in.

Cost of Sewer Maintenance. The cost of maintenance in 1908 was \$63,003.49 of which \$13,884.51 was chargeable to the pumping station. There were 4,732 basins cleaned at a cost of \$1.06 each and 3.94 miles of sewers at a cost of 37 cents per foot. There will be about \$70,000 expended this year (1909) for maintenance of sewers and drains.

DISPOSAL OF THE SEWAGE

Into Passaic River. The sewage of all that portion of Newark not draining to the intercepting sewer and its branches is discharged by gravity through outlets, without purification or treatment, into the Passaic river.

Into Newark Bay. The sewage that is received by the interceptor goes to a pumping station at Avenue J and Mills street, at the southern limits of the built up portion of the city, and is pumped thence through an outfall pipe to a point in Newark bay about 2,000 feet from shore and opposite the mouth of Bound creek.

Outlet Nuisances. The pollution of the Passaic river has been the subject of much attention and legislation for the last 15 years. It is the most important river in New Jersey and is polluted far beyond permissible limits from any point of view. The dry weather flow of the river is at times not over four times the quantity of sewage and manufacturing wastes discharged into it; the latter are putrescible in some cases. Fish have long since ceased to inhabit the stream, and property along its banks has depreciated in value from the unsanitary and unpleasant surroundings.

Future Plans. It is the intention of the city to discharge all dry weather sewage

flow from the entire city, excepting the portion now going to the Joint outlet sewer, into the Passaic valley sewer if it is ever constructed. This sewer, if built, will skirt the west bank of the Passaic river through Newark, extending in a southeasterly direction across the meadows to a screen chamber and pumping station near Newark bay. From the pumping station the sewage will flow by tunnel under Newark bay and Bayonne to a point of discharge in Upper New York bay about one-fourth mile east of Robbins Reef.

In case the Passaic valley sewer is not built it will be feasible to extend the present Newark interceptor area to connect with it the same sewers that would be relieved by the proposed Passaic valley sewer. This would not be of advantage to any of the cities above Newark.

No other plans for the disposal of Newark's sewerage have been made and there is not a great deal of extension work planned.

THE SEWERAGE OF PATERSON, N. J.

General Conditions. Paterson, with a population in 1905 of 111,529, lies at the Falls of the Passaic river where it breaks through First Mountain and sweeps to the east and south in an irregular semi-circular bend about $2\frac{1}{2}$ miles across.

The site of the city is undulating, with hills rising from 100 to 180 feet high.

The conditions in Paterson are favorable to satisfactory and economical drainage, the slopes being steep and the distances to the river not great from any point owing to the bend in the river. In the down-town district there is a sewer outlet at the foot of nearly every street.

The total drainage area in the city of Paterson is about 8 square miles, of which a little more than half is now sewered. The total ultimate drainage area of sewers built is about 83 per cent. of the whole area.

The Sewers. The early records of the sewers of Paterson were lost in a fire some years ago and new maps had to be made from an old report which gave only the sizes and the streets in which sewers had been built. The grades could not be obtained except by making entirely new underground surveys.

The sewers are on the combined system, designed to take both storm water and house sewage. In 1906 there were, from 35 drainage districts, about 29 public sewer outlets emptying into the Passaic, 22 from the south side and 7 from the north side. In addition there are many sewers from factories discharging probably 10,000,000 gallons of sewage a day into the river.

Of the larger sewers on the south side may be mentioned a 54-inch egg-shaped sewer in Prospect street, draining 441 acres, which is said to be adequate for storm

flow, a twin sewer outlet, each barrel being 54 inches diameter, draining 319 acres, in Montgomery street, which is not adequate for storm water; a 60-inch egg-shaped sewer in Thirty-third street, draining 571 acres, adequate for storm water, and a 94-inch circular sewer in Market street, draining 1,504 acres, adequate for the area drained, which is mainly through the 84-inch circular Vreeland avenue branch. There are two main sewers entering from the north side; a 72-inch circular sewer in Hamburg avenue, draining 260 acres, entirely adequate, and a 36-inch egg-shaped sewer in North Straight street, draining 108 acres, which is not adequate. The Market street sewer is the largest and most important in the city.

The size, location, drainage areas and capacities of the sewers of Paterson are given in Table XX.

TABLE XX.
SEWER OUTFALLS OF PATERSON

Street	Size and Shape of Sewer	Present Drainage Area in Acres	Ultimate Drainage Area in Acres	Discharge Cu. ft. per Sec.	Discharge in Inches of Rainfall per Hour		Side entering River
					On present Area	On ultimate Area	
Prospect.....	54" Egg	105.8	440.8	173.0	1.63	0.44	South
Mulberry.....	18" Circ.	3.0	3.0	14.2	4.73	4.73	South
West	18" Circ.	3.0	3.0	8.2	2.72	2.72	South
Bank	24" Circ.	3.5	3.5	20.5	5.81	5.81	South
Main	18" Circ.	16.5	16.5	5.1	0.31	0.31	South
Bridge. ....	.....	47.7	47.7	.....	.....	.....
Montgomery Twin Sewer.....	54" Circ.	348.8	348.8	109.2	0.31	0.31	South
Straight.....	36" Egg	107.5	107.5	14.0	0.13	0.13	South
Franklin.....	12" Circ.	2.0	2.0	5.2	2.56	2.56	South
Keen.....	15" Circ.	23.6	23.6	9.2	0.39	0.39	South
Warren.....	30" Egg	44.6	162.9	45.6	1.02	0.28	South
Lowe .....	.....	4.6	8.6	.....	.....	.....
Wood.....	.....	4.0	8.3	.....	.....	.....
East 5th, Private.....	24" Circ.	3.5	3.5	19.1	5.43	5.43	South
East 11th.....	36" Egg	102.9	102.9	54.9	0.53	0.53	South
4th avenue	30" Egg	29.2	29.2	24.5	0.83	0.83	South
2d avenue.....	30" Egg	22.0	22.0	27.4	1.24	1.24	South
3d avenue.....	30" Egg	52.3	82.5	24.2	0.46	0.29	South
33d street	60" Egg	552.7	571.3	272.5	0.49	0.47	South

TABLE XX—*Continued*

Street	Size and Shape of Sewer	Present Drainage Area in Acres	Ultimate Drainage Area in Acres	Discharge Cu. ft. per Sec.	Discharge in Inches of Rainfall per Hour		Side entering River
					On present Area	On ultimate Area	
20th avenue	42" Egg	18.1	136.0	74.0	4.05	0.53	South
Market street on Vreeland avenue.....	84" Circ.	.....	.....	335.0	0.403	0.22	South
Market street	94" Circ.	820.0	1504.5	960.0	1.15	0.63	South
36" Iron Pipe.....	.....	56.0	56.0	.....	.....	.....
Northwest and Hamburg ave- nue.....	72" Circ.	223.0	260.0	289.0	1.29	1.10	North
North Main and Temple.	30" Egg	13.0	13.0	15.2	1.16	1.16	North
Arch.	30" Egg	30.0	30.0	20.1	0.67	0.67	North
Jefferson	24" Egg	34.0	34.0	17.0	0.49	0.49	North
N. Straight.....	36" Egg	54.0	68.0	45.3	0.83	0.67	North
Bergen.	18" Circ.	5.6	5.6	5.9	1.05	1.05	North
Short .....	.....	21.6	21.6	.....	.....	.....

Population Served with Sewers. The residences of eighty-nine per cent. of the population or about 99,000 were, it is estimated, connected with the city sewers in 1905.

Outlets. All the sewers discharge into the Passaic river. Many of the outlets in the upper part of the city are below the river level causing the sewers to be flooded for some distance back. On account of this there are sludge deposits varying from a few inches to over a foot in depth in these sewers.

Quantity of Sewage. In 1906 two gagings were made showing an average daily flow, after certain corrections were applied, of 20,900,000 gallons per day on April 17-19, and 12,600,000 gallons per day on June 11-12. The first gaging was made at the time of year when the ground water flow is the greatest.

In 1900 there were 71.72 miles of sewers and 1,500 catch basins in the system. In 1906 the City Engineer estimated there was about 80 miles of sewers. In 1906 there were 8,000 house and 500 factory connections. There are a great many factories sewer- ing directly into the river of which there is no record. In 1900 the discharge into the river was estimated at 24,000,000 gallons daily, of which 7,000,000 gallons daily origi- nated in the factories.

MAINTENANCE OF THE SEWER SYSTEM

Inspection. It is stated in a tabulation in a report of the New Jersey State Sewer- age Commission (to the 1900 Legislature, p. 108) that there was at that time a com- plete system of inspection, care and maintenance and that the sewers were "kept care-

fully clean." Later reports (Hazen's report, June, 1906, p. 74) indicate that the inspection and cleaning was not regular and in fact in some cases could not be done at all because many of the manhole heads had been covered over in grading and paving the streets.

DISPOSAL OF THE SEWAGE

Into Passaic River. All the Paterson sewage is discharged into the Passaic river at the sewer outfalls, without treatment of any kind. The result has been the creation of continually increasing pollution and consequent nuisances.

Complaints. Complaints were first brought to the notice of the State Board of Health in 1892, since which time there has been one continual round of condemnation of the condition of the river, which has become a nuisance to residents along the stream, has caused depreciation of property values and is objectionable for manufacturing purposes. Boating, bathing and other ordinarily pleasurable uses are no longer possible.

Attempts to Stop Pollution of River. Numerous bills have been introduced into the New Jersey Legislature to prevent the pollution of the Passaic river from Paterson to Newark bay. Much of the attempted legislation has been very sweeping in its requirements and not always fair to all interests; nor has consideration always been given the participants on points which vitally concerned them. The last bill, and the one under which the Passaic Valley Sewerage Commission is now working for the interests of the whole district, was approved March 18, 1907. This bill requires the various cities to cease polluting the Passaic after December 12, 1912, and provides the necessary authority to allow the Passaic Valley Sewerage Commission to undertake the work for all or any number of the various municipalities in the district.

IMPROVED SEWAGE DISPOSAL

Mr. Gray's Report. Many plans have been suggested and investigated for the improvement of the sewage disposal of Paterson. Two reports of prominence are those of Samuel M. Gray, C. E., of Providence, and Allen Hazen, C. E., New York.

Mr. Gray's report, dated January 15th, 1903, was made to the Citizen's Association and was on the subject of the feasibility of disposing of the sewage of Paterson independently of any other municipality. His findings were that Paterson could dispose of its sewage independently from that of any other community, and in such a manner as not to cause a nuisance to anyone.

His recommendations were, in brief, to locate a plant consisting of septic tanks and sprinkling filters upon land in Bergen County, on the east side of the river, a short distance northerly of the city of Passaic, the sewage to be collected by an intercepting sewer in Paterson flowing to the purification works by gravity and being pumped thence into the septic tanks. The estimated cost, for a daily capacity of

25,000,000 gallons, together with the interceptor, was \$2,670,185; the annual cost of operation not over \$180,435.

Mr. Hazen's Report. On January 1, 1906, Allen Hazen, C. E., was engaged by the Joint Committee on Sewage Disposal, the membership being representatives of the Tax-payers' Association and of the Board of Aldermen, to report on all phases and possibilities of the disposal of Paterson's sewage in the most economical way. The proposition finally narrowed itself down to a comparison between the cost of disposing of the sewage on land not far away, or of joining the trunk sewer movement proposed for the Passaic valley district.

Mr. Hazen made a careful study of the whole problem and finally recommended that Paterson enter into the trunk sewer project only if the raw sewage could be discharged into tide water without treatment; if purification were required then it would be cheaper to treat the sewage near Paterson and allow the purified effluent to flow to the sea through the channel of the Passaic instead of a trunk sewer.

Works Proposed. The estimates were based on an intercepting sewer 5.6 miles long, from Prospect street to Market street, varying in size from 4 feet to 6 feet 6 inches, and costing \$724,900.

From a small receiving reservoir and screen chamber centrifugal pumps were designed to deliver the sewage through 6,300 feet of 60-inch steel pipe to a filter plant across the river.

The purification plant was laid out on the same general lines as the works at Columbus and Baltimore. The sludge was to be used on land for filling or perhaps taken to sea in sludge boats. A 72-inch outlet from the purification plant to the river was to discharge the effluent into the Passaic.

About 35 miles of new sewers would be needed in order to change from the combined to the separate system, which could be extended over a period of 25 to 30 years. The above system was compared, as to cost of construction and operation, with disposal at sea through a trunk sewer in conjunction with other cities. The following is the comparison for both systems.

	Trunk sewer project	Separate Works
Average capital invested per capita.....	\$12 40	\$16 00
Interest and sinking fund at 5% per capita per annum.....	\$ 62	\$ 80
Operating expenses per capita per annum.....	23	48
Storm water separation per capita per annum.....	10	10
Total annual cost per capita.....	\$0.95	\$1 38

The above figures for the trunk sewer project are estimated for a sewer discharging raw sewage into New York bay. If a purification plant is necessary it would cost at least \$0.50 per capita per annum, which, added to \$0.95, would be more than would be required for Paterson to treat her own sewage at home.

Future Plans of the Local Authorities. It is reported that the city of Paterson plans to discharge her sewage into the proposed Passaic valley sewer providing that project is carried out without the necessity of purifying the sewage before discharge into New York harbor. No other definite plan is under consideration.

SEWERAGE OF PASSAIC, N. J.

General Topographical Features. The city of Passaic with a population in 1905 of 37,837, lies on the west bank of the Passaic river one and one-half miles below Paterson. Passaic has grown very rapidly, its population having been, according to United States Census Reports, 6,532 in 1880; 13,028 in 1890, and according to the State Census, 17,894 in 1895 and 37,873 in 1905. Its rapid growth has been induced by the factory facilities afforded by the Dundee Land and Power Co. and by the fact that the city is located at the upper limits of tide water in the Passaic. It is essentially a manufacturing city, although the residential population is large and increasing.

Sewerage. The area of the city is a little over three square miles and has 12 drainage districts of which the largest are 622 acres draining to Lafayette street, 377 acres draining to Brook avenue, 355 acres draining to Aycrigg avenue and 341 acres draining to Hope avenue. The Brook avenue area drains to the river near the southern limits of the city.

The sewers are mostly small and the total quantity of sewage discharged daily not over about 3,500,000 gallons. The trade wastes discharged into the river daily directly from the factories and mills amount to more than twice the city sewage in quantity.

Ventilation is secured through perforations in the manhole covers and cleanliness by the relatively steep grades and the use of flush tanks at summits.

The sewers are designed on the separate system although there are several combined sewers in use, taking both sewage and storm water.

Sewage Disposal. Two of the sewer outlets are on the island (factory section) and discharge into the river above the tail race; two discharge into the main tail race at Washington avenue and Passaic street and several into the river below the tail race. All the sewage and manufacturing wastes go into the river without treatment of any kind.

The river as it reaches Passaic is very foul in summer from the Paterson sewage, and the added sewage from Passaic, of course, increases its objectionable qualities, although the predominating ingredients of the Passaic trade wastes are not of a putrescible nature.

SEWERAGE OF THE CITY OF ORANGE, THE TOWNS OF MONTCLAIR AND BLOOMFIELD AND THE BOROUGH OF GLEN RIDGE

UNION OUTLET SEWER

General Topographical Features. Orange, Montclair, Bloomfield and Glen Ridge are high class residential sections in the Passaic valley. Orange lies west of and adjoins East Orange which, in turn lies west of and adjoins Newark.

Montclair lies north of Orange while Bloomfield and Glen Ridge lie north of East Orange.

Orange, Montclair, Glen Ridge and Bloomfield drain naturally to the branches and main valley of Second river, which empties into the Passaic at the boundary line between Newark and Belleville.

	Drainage Area in Acres.	Population in 1905.
Montclair	3,900	16,370
Glen Ridge	825	2,362
Bloomfield	3,223	11,668
Orange City	1,410	26,101
Totals	<u>9,358</u>	<u>56,501</u>

These total areas and populations are not fully served by sewers.

Sewerage. The sewerage in each of these communities is on the separate system and discharges into the Union outlet sewer which follows the valley of Second river. This sewer was built several years ago, and the cost apportioned among the different municipalities in proportion to the estimated populations in the year 1930, these populations being based on second differences of the five-year census returns for the 20 years preceding the construction of the sewer. The annual cost of operation is apportioned on the basis of actual use, the sewage flow from each town being gauged by suitable devices.

Disposal of the Sewage. The Union outlet sewer discharges the sewage from the territory it serves into the Passaic river at Verona avenue in Newark; no purification is effected.

SEWERAGE OF EAST ORANGE, N. J.

General Topographical Features. East Orange, with a population of 25,175 in 1905 adjoins Newark on the west and includes within its boundaries 3.91 square

miles of gently rolling country. While there are numerous commercial houses in the city it is essentially a residential district containing many fine homes.

The town is underlaid with gravel and sand deposits interspersed with layers of clay. Much difficulty was experienced in laying the sewer from the large quantities of ground water encountered; in fact the contractor for this part of the work failed and threw the burden of finishing it on the township authorities.

Sewerage. The separate system of sewerage is employed in East Orange, storm water being excluded from the sewers. When the plant was first constructed a purification plant, embodying chemical precipitation followed by filtration, was installed and the main outlet sewer led to this plant.

There were upwards of 55 miles of sewers in this district in 1905, mostly small collecting pipes leading to larger mains which in turn join the outfall sewer.

The sewers are provided with automatic flush tanks supplied with water from the street mains.

Ventilation of the sewers is afforded through the perforated manhole covers.

A great deal of ground water enters the sewers, 700,000 gallons daily being the figures estimated in 1890 by a committee of investigation; this quantity was about equal to the domestic flow from the house connections.

Original Sewage Disposal Plant. The original method of disposal was, as above indicated, by chemical precipitation followed by filtration through specially prepared and underdrained areas of land. The sewage entered the works through a baffled channel at the head of which the dose of lime and alum were added to promote the precipitation of the solid matters in the sedimentation tanks. The average dose in the early years of its operation was one barrel of lime and 300 pounds of alum per day at an average expense of about \$6 per day for chemicals. From the precipitation tanks the effluent was conducted, after coarse screening through coke strainers, to the disposal fields covering an area of some 20 acres. The beds were underdrained by lines of tiles at a depth of five or six feet which discharged into Parrow brook.

The soil in the fields proved too retentive and failed to pass the sewage through freely enough, to rectify which three coke beds 6 feet wide, 5 feet deep and 50 feet long were added. It was found, particularly in winter, that the natural filter beds froze up so that the sewage could not pass through; the coke beds, on the other hand, could be worked under all conditions of weather. This plant was put in operation in July, 1888, and was the first of its kind in the country. Its operation was not satisfactory, however, almost from the start, and on July 30, 1890, a committee was appointed by the Town Improvement Society of East Orange to investigate the sewerage system and report on its condition and efficiency. This committee reported February

21, 1891, that the flow to the plant from the 1,200 house connections and 21 flush tanks was averaging somewhat over 1,330,000 gallons daily of which 700,000 gallons daily represented ground water leaking into the sewers. An examination of the effluent from the plant by Prof. Albert R. Leeds showed a satisfactory degree of purification. The cost of the plant was \$95,847.80 and of the sewers, etc., \$322,020.64, a total of \$417,868.44. The average cost of operation was about \$9,000 per year. The committee considered that the system was a success and could handle the sewage from a larger population, but expressed the opinion that ultimately it would be found economical to dispose of the sewage by gravity to tide water through united action with adjacent towns.

Present Disposal. Shortly after this, however, the town of Bloomfield brought suit to compel the city of East Orange to cease polluting the brook, and after passing through one stage of trouble to another, an arrangement was finally made whereby the use of the purification plant was discontinued and the sewage discharged into the Newark sewer system at Newbold avenue, the cost of the necessary sewer connections and changes being borne by the two communities in accordance with the terms of the agreement entered into for the building and operating of the sewer.

Under this contract the city of East Orange was allowed to discharge a maximum of 4,000,000 gallons of sewage into the Millbrook sewer, it having been estimated that the average flow was then in the neighborhood of 2,500,000 gallons daily. The connection with the Newark sewers was made in 1896 since which time the purification plant has not been used.

Hourly gaugings of the flow in 1908 for four successive days showed that the dry weather flow exceeded the amount called for in the contract. On rainy days the sewer sometimes runs full under pressure and discharges into the Newark sewers twice the amount called for by the contract. The night flow was found to be 3,500,000 gallons, indicating considerable ground water flow in the sewer.

In 1905 there were in the district sewered some 4,935 homes. It was estimated that a population of about 20,000 was connected with the sewers.

Future Plans. East Orange has the alternative, in the matter of sewage disposal, of joining in the Passaic valley sewer project, purifying her sewage along modern lines, or constructing an independent outlet sewer to a tidal outlet. No definite arrangement has yet been decided upon in this matter.

SEWERAGE OF CLINTON, GARFIELD, LODI, HASBROUCK HEIGHTS, DELAWANNA, FRANKLIN, NUTLEY, AVONDALE, BELLEVILLE, WOODRIDGE, CARLSTADT, WALLINGTON, EAST RUTHERFORD, RUTHERFORD, LYNTHURST, KEARNEY, EAST NEWARK AND HARRISON.

Sewerage. The towns of Clinton, Garfield, Lodi, Hasbrouck Heights, Delawanna, Franklin, Nutley, Avondale, Belleville, Woodridge, Lyndhurst, Wallington and East Rutherford have no sewers.

Sewers on the separate plan are now under construction at Carlstadt, and Rutherford with three outlets to the Passaic and one or more towards the Hackensack meadows, has a separate system of sewers. The quantity of sewage is small.

Arlington (Kearney) and East Newark, with a combined area of about four square miles have the combined system of sewers. Arlington has three outlets into the Passaic, East Newark one, and Harrison two. Arlington has one outlet toward the Hackensack meadows. The quantity of sewage discharged into the river by the Arlington area is said to be in excess of 7,000,000 gallons daily.

Future Plans. All the above named towns lie in whole or in part in the valley of the Passaic river and are expected to join with Paterson, Passaic and Newark and the other cities in the construction of the proposed Passaic valley sewers, providing the project is carried forward to completion.

THE PROPOSED PASSAIC VALLEY SEWER

Origin of Project. Until about 1893 the condition of the Passaic, while not unbearable, had been growing noticeably offensive; in 1894 it was worse, and in 1895 it had reached a point that demanded attention. Growing out of the agitation over these conditions an Act was introduced into the State Legislature, which was approved February 26, 1896, appointing a commission to consider the subject of the pollution of the Passaic river, and of a general system of sewage disposal for the relief of the Passaic, an appropriation in the sum of \$10,000 being made to meet the expenses of the investigations.

First Report. The Commission's engineers, Mr. Alphonse Fteley, of New York, and Mr. Charles E. A. Jacobsen, of Newark, completed their investigations on February 2, 1897, six months after their appointment, and the Commission forwarded its report to the Legislature during the same month. Briefly stated, the recommendations were, to establish a sewerage district including the whole of the country tributary to the Passaic below the great falls at Paterson and construct an intercepting sewer along the river to collect all the sewage discharged therein and conduct it to a pumping station south of Newark, and deliver it thence, without purification to a terminus into

Newark bay. The further recommendation was made that if experience should show that a more complete system of disposal should become necessary, the outfall should be extended across Staten Island to the outer New York harbor.

Subsequent Reports. Since that report was made to the Legislature the subject has been investigated and reinvestigated and reported upon a number of times, the matter eventually taking definite form by the establishment of the limits of the proposed district by Legislative Act in 1902. The plan recommended to the Legislature of 1903 by this Commission proposed an intercepting sewer along the west bank of the Passaic river from the great falls at Paterson to a pumping station on the Newark meadows, the sewage to be pumped thence through steel force mains under Newark bay into a main sewer across Bayonne to an outfall in New York bay near Robbins Reef Light. This project was thoroughly investigated by the New York Bay Pollution Commission and reported upon adversely in 1905 and 1906.

Present Commission's Plan. The present Passaic Valley Sewerage Commissioners are proceeding under Chapter 10, Laws of New Jersey, Session of 1907. Their report to the municipalities lying in whole or in part within the Passaic valley sewerage district is dated April 20th, 1908, and recommends the construction of an intercepting sewer of greater capacity than the earlier reports, following essentially the same course from Paterson to a pumping station at Newark bay. At this point the main sewer will be 13 feet 6 inches in diameter and at a depth of 26 feet below high water; and pumps are to lift the sewage to a height of 15 feet above high water to a well which is to be connected with a tunnel 12 feet in diameter extending under Newark bay, Bayonne and New York bay to the outfall at the edge of the deep channel near Robbins Reef Light. The plans provide for the passage of the sewage through a grit chamber to "remove all gravel, sand and other heavy matter and through a screen chamber where all floating matter will be removed." The outlet sewer is to be "extended by a number of smaller outlet pipes at right angles to the current of sea water so as to get the greatest possible dispersion over a large area." The outfall pipes are to "discharge at a depth not less than 40 feet below mean high water." "They will be extended in different directions and in varying lengths across the channel, and will be provided with discharge openings, venting the sewage in small units horizontally in the direction of the tidal current over a sufficient area, and by such number of vents as will produce a rapid assimilation of the discharge with a very large volume of bay water."

Opposition. When the report suggesting the discharge of the sewage from this large and rapidly growing district into New York bay was made public, adverse criticism was aroused concerning the discharge of the sewage in its raw or unpurified form into the

harbor. A public hearing was held to discuss the matter before the Harbor Line Board in New York, following application to the War Department by the Passaic Valley Sewerage Commission for permission to construct the outlet sewer into the harbor. At this meeting the views of many associations and individuals were expressed and the matter taken under advisement by the Harbor Line Board. Application was then made by New York State to file an injunction to prevent the discharge of the Passaic valley sewage into the harbor. The hearing on this application was set for January 6th, 1909, before the United States Supreme Court at Washington, D. C. After the suit had been brought the United States Government intervened in the suit in order to become a co-plaintiff.

Investigations and Government Control. In the meantime Col. Wm. M. Black, Chief Engineer Officer, Department of the East, reported to the Adjutant General of the East that, as a result of the hearings before the Harbor Line Board and personal examinations, if local nuisances could "be avoided and the quantity of sewage limited to an amount which the body of water in question could care for, no evil effects were to be anticipated." Working on these premises an agreement was reached between the War Department and the Passaic Valley Sewerage Commissioners under which permission was granted for the discharge of the sewage into the harbor. The terms of the agreement are in effect that the sewage must be screened through coarse screens, passed through a grit chamber, screened through screens having openings of four-tenths of an inch and settled for an hour; that it must be discharged into the harbor in deep water through multiple outlets in a manner to prevent serious local nuisances and that the discharge shall not injuriously affect major fish life. The agreement also provides that the works shall at all times be subject to the inspection of proper Government officers, shall be capable of producing the results called for and be operated in a manner to live up to the terms of the agreement.

Extent of the Proposed Works. This project, as proposed, is intended to give relief to the Passaic river by diverting therefrom the sewage of all the cities and towns now draining into it. These municipalities and suburban districts had a total population in 1905 of 601,817, residing on an area of 103.23 square miles tributary to the sewer, 76.62 square miles being included under the terms of the Law of 1902. The sewer is designed with capacity estimated to be sufficient to take the sewage of a population in 1940, of 1,649,440 people, amounting to 357,365,200 gallons per 24 hours, of which 247,416,000 represents house sewage, 47,467,100 ground water leakage into the sewers, and 62,482,100 gallons the sewage from manufacturing and trades uses. Thirty municipalities are included within the territory to be served, 50 per cent. of the total population in the district residing in Newark and East Orange.



The Hudson River Looking North from the Battery. The sewers generally discharge under the ends of the piers



Upper New York Bay Looking South from the Battery. Ice is flowing down the Hudson, around the Battery and up the East river

The volume of sewage that will be discharged from the Passaic valley sewer, as soon as it is constructed, will be about one-half of the present quantity of domestic sewage discharged by all the sewers of Brooklyn.

The sewage as it will reach the pumping station, south of Newark, will be stale. Substantially all the floating solids excepting the resistant ones, such as sticks and corks, will be ground up and practically reduced to a state of solution during the long time required for passage through the sewer. It is probable that but a very small percentage of the decomposable matters in the sewage will be arrested by the screens before discharge into the harbor. Although there may be relatively few visible particles in the discharged sewage, the organic matter therein will be in a putrefying condition, and will have great avidity for the already deficient supply of oxygen in the harbor water.

It has been contended that the sewage which it is proposed to discharge into New York harbor through the Passaic valley sewer already reaches these waters by its passage through Newark bay and Kill van Kull. It must be remembered, however, that before the New Jersey sewage can reach New York harbor under present conditions it will have been exposed to the influences of subsidence, bacterial decomposition, oxidation and dispersion. By the time it reaches the Upper bay it is much changed and in a greatly diluted condition. The Passaic valley plan is to discharge the sewage in a crude state, though freed from visible suspended matters, into the center of the Upper bay, thereby relieving Newark bay at the expense of New York harbor. The waters of the Upper bay and the Hudson river are at present heavily charged with sewage; they contain on ebb tides about sixty-five per cent. and on the average of ebb and flood tides about seventy-one per cent. of the amount of dissolved oxygen necessary for saturation.

As fish will not thrive in waters containing less than 50 per cent. of the normal quantity of dissolved oxygen, the waters of the Upper bay and the Hudson river between Spuyten Duyvil and the Battery on ebb tides have a margin of safety only one-third in excess of the amount necessary to support fish. The discharge into the Upper bay of the sewage from the Passaic valley sewer district, the amount of which would be about one-tenth of the quantity of domestic sewage from the entire metropolitan district as soon as the Passaic valley sewer shall have been put in operation, would cut down the safe margin of dissolved oxygen required for the support of fish life in the Upper bay and Hudson river on ebb tides.

The discharge of so large a quantity of sewage into the harbor in one locality, even though the outlets be scattered over an area of several acres, would reduce the dis-

solved oxygen, at times of imperfect dispersion, to so low a point as to lead to danger of putrefaction and the consequent evolution of foul odors.

In the suit which was brought against the Passaic Valley Sewerage Commission and the State of New Jersey by the State of New York, the United States Government became a party to the suit by intervention and the agreement which was entered into between the United States Government and the Passaic Valley Sewerage Commission does not terminate the suit as between the State of New York and the Passaic Valley Sewerage Commission. The interests of the United States Government are mainly in the prevention of the shoaling of the waters which might interfere with navigation. The government is not essentially interested in the pollution of the waters as affecting the health conditions surrounding the City of New York; its interest in this connection concerns the health of the troops and government employees. The interests of the City of New York in the effect of harbor pollution are vastly greater than those of the United States Government.

Recommendation. As the Government has reached an agreement which is apparently satisfactory for the protection of its interests the Metropolitan Sewerage Commission recommends that the City of New York apply to the Supreme Court of the United States for permission to intervene in the suit now pending between the State of New York and the State of New Jersey and the Passaic Valley Sewerage Commission, in order to protect the public health and welfare of its citizens.

Future Prospects. Considerable uneasiness has been felt by some of the New Jersey communities comprised in this project owing to the possibility of increased cost due to the necessity of partially purifying the sewage before discharging it, the project being of advantage only if less expensive to maintain than independent purification plants would be.

JOINT OUTLET SEWER FOR THE SEWAGE OF IRVINGTON, VAILSBURGH,
SOUTH ORANGE, WEST ORANGE, SUMMIT, MILLBURN, AND
PARTS OF ELIZABETH, NEWARK, ORANGE AND UNION TOWN-
SHIP

GENERAL FEATURES AND CONDITIONS

Principal Topographical Conditions. The district served by the Joint outlet sewer, which is directly west of Newark, East Orange, Bloomfield and Montclair, lies along the small tributaries and upper valleys of the Rahway and Elizabeth rivers.

The areas drained may be characterized, in general, as non-uniform, hilly slopes, underlaid with all varieties of formations from solid rock to quicksand and water-bearing drift.

Vailsburg and Irvington drain into the Elizabeth river; Summit into the Passaic and Rahway and all the remaining territory into the Rahway river.

The tributary areas, populations and main features of the topography are given in Table XXI.

TABLE XXI

JOINT OUTLET SEWER DISTRICTS

Municipality	Population		Area	Features
	1900	1905	Sq. Miles	
Elizabeth .....	.....	4,500	1.08	
Roselle Park.....	2,000	4,500	....	Lies very flat
Irvington.....	5,255	7,000	2.03	Hilly—rock
Vailsburg	2,000	3,000	1.26	Hilly—little rock
Newark	2,200	3,500	.47	
South Orange.....	4,608	5,500	2.46	Non-uniform hill slopes
West Orange.....	6,899	8,200	3.63	Non-uniform hill slopes
Millburn.....	2,500	3,500	4.38	In old bed—Passaic river
Summit	5,580	6,500	6.01	Must reverse direction of flow from Passaic and tunnel
South Orange Township	1,800	2,500	5.86	
Union Township.....	2,000	2,500	3.90	
Totals.....	34,842	51,200	31.08	

South Orange's Need for Sewerage. The first need for a system to care for the sewage of any of the towns of this district was felt about 1895, when suggestions by engineers for South Orange favored a disposal plant instead of a joint outlet sewer. A farm in Millburn Township was purchased for a disposal field but protests and a permanent injunction brought the project to an end. The court held that one municipality could not purchase land in another for sewage disposal without consent, and this Millburn refused to give.

In 1896 F. T. Crane recommended discharging the South Orange sewage into Newark bay north of Elizabeth; Alexander Potter recommended its discharge into tide water south of Elizabeth. Mr. Crane's plans were accepted, and Rudolph Hering and James Owen retained as Consulting Engineers to review the plans. When protests were made against the emptying of the sewage into Newark bay it was suggested to discharge it into one of the tributaries of Bround creek. Newark protested against this and a change in administration stopped all independent action by South Orange.

First Joint Action. A meeting of the representatives of South Orange, West Orange, Irvington, Vailsburg and Newark was held and on August 10th, 1898, Alexander Potter was instructed to make plans, surveys and estimates "for a trunk sewer to tide water capable of accommodating the present and prospective future population

of these towns, or portions of these towns, draining towards the Rahway and Elizabeth rivers." Mr. Potter's first preliminary report was made on September 29th, 1898, and contained the following recommendations:

- (1) The adoption of an outlet into Kill van Kull, south of Elizabeth.
- (2) The sewer to be 27 inches in diameter.
- (3) The adoption of a high level sewer, keeping out of river bottoms.
- (4) Provision for a population of 106,000.
- (5) Provision for storage tanks where necessary to equalize flow.
- (6) Provision for underdrainage where necessary.

Legislation. There was some doubt whether the existing New Jersey Laws would permit a collection of municipalities to act together in the desired manner and a Law was, therefore, prepared and enacted to permit two or more municipalities in that State to construct a joint outlet sewer.

A permanent organization under this Law was affected March 27, 1901. The State Sewerage Commission gave consent to the outlet, at the foot of Bayway, into Staten Island Sound "with the proviso that should future exigencies make treatment necessary, it would be required," and the United States authorities were consulted in regard to the discharge of this sewage into navigable waters, which point the government held to be outside of its jurisdiction.

Contract with Elizabeth and other Municipalities. In lieu of payment for right of way through Elizabeth the following concessions were agreed upon:

- (a) The granting to Elizabeth of 100,000 cubic feet per diem of capacity in the trunk sewer along the length of Bayway.
- (b) The increasing of the size of the sewer from Staten Island Sound to Woodbridge avenue from 42 inches to 66 and 72 inches in diameter to provide for storm water sewerage facilities for the lower portion of Elizabeth.
- (c) The construction of a wharf and bulkhead at the outlet on the Sound.

Legislation was secured to allow the admission into the organization of Morristown, Morris Plains, Chatham and Madison, which lay outside of the line of the sewer. Roselle Park and Union Township were also admitted upon payment of a fixed sum.

Execution of Project. Work of construction was formally started on the first contract March 27th, 1902, one year from the date of the organization, and in October, 1903, Irvington was allowed to connect to and to use the sewer. This use put the Joint outlet project on the same footing as all other cities and towns maintaining outlets at tide water in the vicinity of New York and the possibility of the work being held up by injunction from any source was at an end.

The whole work was finally completed and accepted June 16, 1904. At this time a permanent organization for the maintenance of the sewer was effected.

ORGANIZATION OF MUNICIPALITIES

For Construction. The first meeting was attended by the governing bodies of the municipalities concerned. Various executive officers and an engineer were elected by ballot. Later a bill was proposed and enacted, enabling one representative from each municipality "to legally transact the business of the joint meeting for his municipality."

For Maintenance. Practically the same organization was effected for the maintenance as for the construction, with the addition of inspectors reporting to the Chief Engineer.

SEWERAGE WORKS

Design. The Joint outlet is designed for an ultimate population of 150,000. It has a capacity of 21,000,000 gallons daily, or 140 gallons per capita per day for the ultimate population.

Separate System. The Joint outlet sewer was designed to take house drainage only, but the municipalities are not restricted as to the use they may make of their allotment of capacity. Each city pays for its maintenance on the basis of the quantity discharged by it, so that it would not seem to be good business policy to include roof drainage and street wash. It is undoubtedly true that more or less storm water does enter the sewers as several reports mention the fact of the sewer being overtaxed during storms.

Velocity of Flow. It was the intention to have the velocity at least 2.5 feet per second when running half full, but in most cases three feet per second has been secured.

Recording Gauges. Thirteen recording gauges to register the depth of flow in the sewers were installed. From these records the amount of sewage delivered by each municipality is determined.

Equalizing Tank. Provision was made in the plans of both the east and west branches for storage tanks to equalize the 24-hour flow, as it was assumed that 50 per cent. of the total flow would be concentrated in eight hours' time. By means of these reservoirs it was hoped to double the capacity of the main line, at a cost not to exceed 25 per cent. of the cost of duplicating it.

The Sewer. The main sewer extends up Bayway and parallel to the Elizabeth river to Union avenue, making provision for admission of 750,000 gallons daily of Elizabeth sewage along Bayway and for receiving the sewage from the Elizabeth interceptor at Woodbridge avenue. The diameter of the sewer is 72 inches up to Burlington avenue, 66 inches to Woodbridge avenue, and 42 inches to Union avenue, where the east and west branches come together. The main sewer was built of brick except that cast iron pipe was used in crossing under streams. It was aimed to keep

the line as high as possible to avoid seepage of ground water into the sewer but even then about two-thirds of the trenches were wet and much quicksand was encountered.

West Branch. The west branch of the sewer extends in a northwesterly direction under the divide between the Elizabeth and Rahway rivers. The 3,000 feet of tunnel was a difficult and expensive piece of work. Just north of the Rahway river crossing the line branches to the right up the river valley to receive the South and West Orange and South Orange Township sewage and to the left for that of Milburn and Summit. Provision was made in the design for storage tanks to be located at Jefferson avenue, in Orange Township, to equalize the night and day flow when the day flow should equal the carrying capacity of the sewers.

East Branch. The east branch of the sewer extends up the Elizabeth river into Irvington and Vailsburg and drains also a part of Newark lying within this watershed. A second storage reservoir was designed for this branch; it was to be located below the ice ponds on Union avenue. The following extract from the 1908 report of the State Board of Health would indicate that the time had arrived for the construction of the reservoir:

"The trunk sewer supplying Irvington and Vailsburg and emptying at Bayway below Elizabeth, is apparently of insufficient size to take care of an extra amount of sewage, especially at times of heavy rains. To remedy this two outlets of 15-inch terra cotta pipe have been attached to the trunk sewer at Irvington, emptying into the Elizabeth river at a point opposite the Irvington Cemetery." Notice was served to cease polluting the river, but was not complied with.

Outlet. The outlet is situated at the foot of Bayway, Elizabeth. A special bulkhead and wharf were constructed with the sewer terminating at the dock line instead of in the center of the channel as originally designed. The State Board of Health gave permission for this rearrangement. The 72-inch brick sewer terminates at the upper end of the wharf in a 7½-foot square chamber from which three lengths of 36-inch cast iron pipe lead to the dock line.

Extent of System. About 45 miles of main sewers and laterals had been constructed up to 1905, about 55 miles since then have been put in and it is estimated that some 60 miles more will be added in the next ten years.

MAINTENANCE OF THE SYSTEM

Inspections. Two regular inspectors under the Chief Engineer were allotted a portion of the sewer to patrol and report upon each week; they also look after the recording gauges. Frequent trips of inspection are made by the Chief Engineer or one of his assistants.

Cleaning. Apparatus for cleaning and flushing and making repairs are stored at convenient points to be used in emergencies.

Leakage of surface water into the sewer, through perforated manhole covers has been found to be a large item. An average of 1.1 gallons per minute per manhole was estimated to enter the system during a warm rain storm on top of 5 to 6 inches of snow. The remedy was to raise the manhole heads in some cases and to plug the holes in the covers in others.

Entrance of Ground Water. Provision was made in the design of the sewer for the entrance of ground water in an amount equal to one-half of the sewage flow; less than 10 per cent., it is estimated, is actually found. It was believed that the leakage might in that district be kept down to 25,000 gallons per mile with rigorous inspection, using cement joints, and to 5,000 gallons per mile using sulphur sand joints.

DISPOSAL OF THE SEWAGE.

Tidal Discharges. The joint outfall sewer discharges its contents into the waters of Kill van Kull at the face of the wharf at the foot of Bayway, Elizabeth, through three 36-inch cast iron pipes with their invert placed 5.5 feet below low tide elevation.

Investigations. Experiments were made during the preliminary investigation to determine the limits of dispersion of the sewage by casting floats adrift off the point of discharge at all stages of the tide. From these it was concluded that the sewage, or what was left of it, would pass out of the Kills on the subsequent tide without reaching the shore at any point.

Effects of Discharge. Some eighteen months after the completion of the sewer, Mr. Potter states in his report that "no injurious effects can be detected, although the average flow of sewage now exceeds 4,000,000 gallons in twenty-four hours. * * * It is the opinion of the writer that this outlet will afford a satisfactory means for the disposal of the sewage of the territory benefited for all time."

In 1908 upwards of 6,000,000 gallons daily discharged into Kill van Kull through the Joint outlet, and that conditions may have changed somewhat is gathered from the following extract from the report of the State Board of Health for 1908 (p. 438).

"This sewer empties into the Staten Island Sound below Elizabeth and causes considerable nuisance and pollution in that body of water."

Future Condition. There is now being constructed in Elizabeth a trunk sewer and interceptor to take practically all of the dry weather flow emptying into the Elizabeth river and discharge it into the Joint outlet. This sewer is 42 inches in diameter and designed to ultimately carry away the sewage of 100,000 people with an allowance of 50 gallons of sewage per capita per day. It is thus seen that ultimately 250,000 people are expected to be tributary to the Joint outlet and to deliver 26,000,000 gallons of sewage daily into the Sound where the State Board of Health has already called attention to the considerable nuisance and pollution caused by less than one-fourth of this amount.

FUTURE PLANS OF LOCAL AUTHORITIES

Disposal. In Elizabeth it is recognized that in the future it may be necessary to purify the sewage; and when that time arrives the Joint outlet organization will cooperate in taking care of the sewage in such manner as may prove the most economical and efficient.

Extensions. It is estimated that about 60 miles of sewer extensions in undeveloped territory will be built during the next ten years. The town of Morristown has not gone into the Joint outlet although capacity was provided for it.

SEWERAGE OF ELIZABETH

GENERAL FEATURES AND CONDITIONS

Principal Topographical Features. Elizabeth with a population in 1905 of 60,509, is situated to the northwest of Staten Island and to the west of Newark bay. It has a waterfront of nearly one mile on Kill van Kull and three miles on Newark bay, and extends back from the water-front about three miles. The northeastern portion, from the Central Railroad of New Jersey to Bound creek and east to Division street is uninhabited meadows but a few feet above sea level. Another swamp area extends along the Elizabeth river from Summer street and Third street southwest to the boundary line of the city.

The whole surface of Elizabeth is comparatively flat, the highest knolls rising to but 50 feet above sea level. The east side has a rather poorly defined ridge starting from North Elizabeth and running to Elizabethport parallel to and about one-half mile distant from the river. The slopes on the west side are somewhat steeper, particularly near the river and in the neighborhood of Grand street.

Elizabethport drains into the Kill van Kull and Newark bay. A portion of North Elizabeth east of the Pennsylvania Railroad drains into small creeks in the meadows. The remainder of the city drains into the Elizabeth river.

SEWERAGE WORKS

Organization for Construction and Maintenance. The City Engineer has charge of designing and constructing the sewers; they are maintained by the Street Commissioner's department. Inspectors for construction work are named by the Street Commissioner, but as the inspectors are not as a rule trained for such duties the Engineer looks after the work with his own men whom he has the power to employ and dismiss. Civil service rules are not adopted in Elizabeth. Sufficient funds are allotted the Engineer for carrying on his work, but the funds for maintaining the sewers are, on the other hand deficient.

THE OLD SYSTEM

Sewers. The old sewers in Elizabeth were built to carry both storm water and house drainage. They were not designed of sufficient size to carry the heavier rain storms from fully developed areas and are inadequate, particularly in Elizabethport where at times the manhole covers are thrown off by the pressure from the floods within as the excess water escapes and floods the streets. The larger sewers are all made of brick and are egg-shaped or circular. Concrete, as a material of construction for sewers, is not favored in Elizabeth.

Very little ground water enters the sewers of Elizabeth. A portion of the excavation for the new interceptor was through solid rock, which was shattered by the blasting and it is thought that ground water may follow along the outside of the sewer barrel and a small amount leak into the sewer; serious trouble, however, is not anticipated.

Old River Outlets. There are twenty-one outlets of various sizes emptying into the Elizabeth river; one of the largest being the 7-foot Mill lane or Westfield avenue sewer. This sewer drains a residential area of some 1,200 acres north of the Pennsylvania Railroad and east of the river, where the houses are far apart and the properties are not yet fully developed. For a mile south of Westfield avenue sewers discharge into the river at the foot of nearly every street. A 42-inch brick sewer down Third street empties into the river near its mouth; this sewer is laid on a plank grillage across the swamp and has given good service.

Elevation of Outlets. Most of the sewers discharge under water at high tide, the invert being in the neighborhood of low water.

NEW SYSTEM

Design. The Elizabeth interceptor is circular in shape, with a vitrified brick invert and common brick arch. The carrying capacity was calculated using Kutter's formula with $n=.013$. The slope is uniformly one foot in 1,000, and running half full the maximum velocity is estimated at 3.2, and the minimum at 2.5 feet per second.

Sizes. The Joint outlet sewer, from South Orange is 66 inches in diameter, from Woodbridge avenue to Burlington avenue and the 72 inches in diameter to the outlet. The agreement by which this sewer was permitted to pass through Elizabeth gave to her unlimited capacity from Woodbridge avenue south and 100,000 cubic feet capacity per day north of this point.

The Elizabeth interceptor is 42 inches in diameter from the pumping station to the Joint outlet and 40 inches from the pumping station north, diminishing in size according to the territory drained into it by the various sewers.

Capacity. A population of 100,000 some 100 years hence has been provided for. This is equivalent to five persons on a lot 25 feet wide and 100 feet deep, or eighty-seven people per acre. The amount of sewage per capita was estimated at 50 gallons per day with half flowing off in six hours; or at the rate of 100 gallons per capita per day.

By deducting the water used by the factories from the total metered consumption, 60 gallons per capita per day was found to be the amount used for domestic consumption, including waste.

Ventilation. Ventilation of the sewers is accomplished by using perforated man-hole covers through which the air circulates.

Interceptor. At the present time an interceptor is being constructed to collect the dry weather flow from all of those sewers now emptying into the Elizabeth river from Westfield avenue south to Summer street; this interceptor has two branches on the east side which cross the river at South street and Pearl street respectively.

Pumping Station. A pumping station is provided at Summer street and Clarkson avenue to raise the sewage some 16 feet, which is sufficient to discharge it into the Joint outlet sewer at Woodbridge avenue and Bayway.

Three 8-inch, centrifugal pumps direct connected by vertical shafts to 16 horsepower motors are being installed at the pumping station. The motors will be automatically started and stopped by a large float resting on the sewage in the pump well; this float makes and breaks the electrical connection at certain fixed levels. An attendant is expected to visit the float two or three times a day in addition to looking

after the various tide and intercepting valves at the points of connection with the combined sewers.

Discharge Outlet. The discharge of the Joint outlet is at the foot of Bayway into the Kill van Kull. This point is looked upon at Elizabeth as one of the most favorable obtainable, and as satisfactory, the water being deep and the currents swift enough to carry the sewage away.

Extent of System. The number of miles of sewers, number of outlets and house connections, the estimated population served by the sewers, and data on the amount of water consumed are given in Table XXV.

TABLE XXV
GROWTH OF SEWER SYSTEM OF ELIZABETH

	Miles of sewers	Number of outlets	Estimated number of house connections	Estimated population served	Water Consumption per capita	
					Total	Domestic
1900.....	29	13	.....	50,000	150	60
1905.....	42	....	.....	.....	....	..
1908.....	69.7	....	.....	.....	....	..
1909.....	..	29	10,000	60,000*	....	..

*It is estimated that half this population is tributary to the new Interceptor.

MAINTENANCE OF THE SEWERAGE WORKS

Cleaning. The streets of Elizabeth are kept fairly clean and the sewer catch basins are cleaned at varying intervals. The Street Commissioner does not allow the street sweepers to push sweepings into the sewers; the rule is thoroughly enforced. There is not sufficient appropriation to clean the sewers and basins as often as desirable. The basins are comparatively small and trapped with a flagstone. The sewers and basins are cleaned by hand.

Disposal of Cleanings. The cleanings from sewers and basins are dumped upon meadow lands together with the garbage. The dumps are too far from houses to cause any nuisance; it is realized, however, that the time will come when this will not be permitted and some other system of disposition will have to be devised.

DISPOSAL OF THE SEWAGE

Tidal Discharge. The Joint outlet sewer empties into Kill van Kull at the foot of Bayway, Elizabeth, in addition to which there are four other large sewers emptying

into the Kill van Kull and Newark bay. The Elizabeth street sewer has a branch interceptor along Front street draining the sewers in four streets to the east of Elizabeth street. A 4-foot by 5-foot 6-inch sewer running down Trumbull street drains the eastern portion of Elizabethport; the lower end of this sewer running through the property of the Singer Manufacturing Company was built by that company in consideration of which they were allowed to close the street.

Meadow Outlets. A combined sewer in Alina street and a storm water sewer in Fairmount avenue, taking a small portion of house drainage, empty into small tidal creeks in the meadows.

River Outlets. The 21 outlets into the Elizabeth river will be done away with, except for storm water overflow, when the new interceptor is completed and put in service.

Nuisances. The river outlets have been very offensive and have caused extensive filling in, particularly by the Mill lane sewer.

Mr. W. H. Luster, Jr., City Engineer of Elizabeth, describes the condition* of the river, thus:

“Sewage has made deposits along its sides and bed and has caused it not only to be an unsightly and forbidding spectacle to travellers over the bridges, but we have its odor whenever the weather is warm enough to cause fermentation of the deposited filth.”

Complaints. No suits have been instituted on account of the condition of the river, but efforts to have the offensive conditions abated were begun in the early nineties. In 1896 Mr. Francis Collingwood reported on the situation and suggested means for taking the dry weather flow out of the river and pumping it to the Kill van Kull through Bayway.

No complaint is made of conditions at the outlets of the Elizabethport sewers although these all empty at the bulkhead.

FUTURE PLANS OF LOCAL AUTHORITIES

Ultimate Disposal. It is recognized that at some future date it will be necessary to purify the sewage of Elizabeth before discharging it into a stream or body of tidal water. Looking forward to this time, a tract of meadow land to the south of the pumping station has been suggested as the proper point to treat not only the sewage of Elizabeth but probably that coming down the Joint outlet sewer. No study has been given to the type of purification required nor to general plans for collecting the sewage of Elizabethport.

*New Jersey State Sewerage Commission's Report for 1909, p. 128

SEWERAGE OF THE HACKENSACK VALLEY

The Hackensack river lies between the Passaic and the Hudson, and flows nearly south into the head of Newark bay. The principal towns in the Hackensack valley, within the limits of the metropolitan district, are Tenafly, Englewood, Hackensack, Ridgefield Park, Ridgefield, Mossmere, Palisades Park and Leonia. Several of these towns have sewerage systems which discharge into the Hackensack river or its tributaries.

To the north of the metropolitan district are a few other small towns draining into the river.

SEWERAGE OF HACKENSACK

Hackensack, with a population of between 12,000 and 14,000, lies four and one-half miles east of Paterson and Passaic. The sewerage problem of Hackensack has been comparatively simple, except for the complications arising from the necessity of discharging the sewage at a low elevation and also those involved in the construction of combined sewers with sufficient capacity to provide for the future growth of the borough. Of the four main outfall sewers, the most northerly is the Anderson street sewer, an old 5-foot brick sewer of circular section, built 35 years ago, the invert of which was laid in a wooden cradle without mortar joints to allow it to serve to some extent as an underdrain for the soil. One branch of this sewer extends about a mile to the north through Fairmount; the other principal branch swings over slightly to the south and runs out the main street leading through Maywood to Paterson and Ridgewood. This branch is about three-fourths of a mile in length. Both branches of this sewer reduce in size as higher elevations are reached.

The next sewer to the south is also a 5-foot sewer, known as the Main-Bridge street sewer. This discharges into the Hackensack river north of the bridge across that stream. The tributaries of this sewer extend up Main street and other streets parallel thereto to beyond the tracks of the New York, Susquehanna & Western Railroad, and drain the greater part of the city south of the territory that is tributary to the Anderson street sewer. Just to the south of the bridge, and below the discharge outlet of the Main street sewer, is a reinforced concrete sewer 4 feet by 9 feet in section, known as the creek sewer. This has a storm water outlet to the creek, and also a pipe extension to carry the dry weather flow out to the Hackensack river. It extends back to near the New Jersey and New York Railroad tracks with a branch extending northerly and draining a considerable territory to the west of the tracks. It serves to relieve the Main street sewer from some of the storm water which originally was tributary thereto and caused serious sewer floods.

One-quarter of a mile south of the outlet of the creek sewer a 3-foot brick sewer discharges into a small estuary of the Hackensack river and takes the sewage of the balance of the Hackensack territory.

SEWERAGE OF BOGOTA

Across the river from Hackensack lies a small settlement called Bogota which has three sewers discharging into the Hackensack river; a 2-foot brick sewer which empties into the river about one-fourth of a mile above the New York, Susquehanna & Western Railroad bridge, a 12-inch sewer emptying into the river at the Bogota railroad station and another small pipe sewer emptying in about one-eighth of a mile below the last mentioned sewer.

SEWERAGE OF RIDGEFIELD PARK

Ridgefield Park, which has a population of between 2,000 and 3,000, lies upon a narrow strip of ground rising to a height of a little over 100 feet above the Hackensack meadows. The most northerly sewer in Ridgefield Park is three feet in diameter and empties into the Hackensack river about one-half mile above the railroad station. A 3-foot 6-inch brick sewer enters the river at Mt. Vernon street, near the railroad station, another of the same size enters at Brinckerhoff avenue, a third sewer of the same size at the Tea Neck road and a 3-foot sewer at Ridgefield avenue, near the draw-bridge. The sewers of Hackensack and Ridgefield Park are all on the combined plan.

THE SEWERAGE OF THE OTHER TOWNS ON THE WEST SIDE OF THE HACKENSACK VALLEY

Of the other towns on the west side of the Hackensack valley below Hackensack, Hasbrouck Heights and Woodbridge have no sewers, but Carlstadt has a system of separate sewers just installed, but not yet in operation; the sewage is to be pumped to settling basins from which it is to be discharged into a canal or small stream tributary to Berry creek.

SEWERAGE OF THE TOWNS ON THE EAST SIDE OF THE HACKENSACK VALLEY

Ridgefield. Ridgefield is a settlement of about 750 people, on the road leading from Ridgefield park to Edgewater. The sewerage works consist of one outlet pipe discharging into a drainage channel leading to the Hackensack river from near the Ridgefield railroad station.

Mossmere and Leonia, the next settlements north of Ridgefield, have a population of about 1,500 and are sewerred through one 12-inch pipe to Overpeck creek.

Palisades park, with a population of 911 in 1905, is served by two 12-inch pipes leading to Overpeck creek, one being located at the end of Central boulevard and the other at the end of Edsall boulevard. At Leonia which is the next town above Palisades park a 12-inch pipe leads to Overpeck creek from about the center of the town.

SEWERAGE OF ENGLEWOOD

Englewood is one of the most attractive suburban towns, topographically, in the neighborhood of The City of New York. It is justly celebrated for its beautiful trees and homes; its population in 1905 was 7,922.

Englewood is completely sewered on the separate plan, the sewerage works being controlled by a company operating under a franchise. Sewage is collected from the various small laterals to a main outfall pipe leading to a canal which discharges through the marshes into Peapack creek at the head of its tidal channel.

This canal has been the subject of much complaint, and many threats have been made by property owners to compel the sewerage company to abate the nuisance created by its works. The extent of the changes and improvements that have been made appear to have consisted usually of cleaning out the canal when the complaints have been so persistent as to make it impossible to ignore them.

FUTURE PLANS FOR THE HACKENSACK VALLEY

Owing to the considerable growth of the villages, principally on the Peapack and Tienekill creeks, much concern has been felt as to the necessity for improved methods of dealing with the municipal wastes from these communities. This has lately brought together several of the prominent citizens of the district for the purpose of discussing the feasibility of starting a movement for the construction of a joint sewer from Tenafly to a purification plant to be located near the confluence of the Peapack and Hackensack rivers. This plan would be in consonance with the action that has been taken by the citizens of other portions of the metropolitan territory in that vicinity.

The only important source of pollution of the Hackensack, above the town of Hackensack is at the village of Delford, with a population of 841, where the Hackensack Water Company has its main supply dam and water filtration plant. New Milford and Oradell together are known as Delford, and are sewered on the separate plan, one outlet being an 18-inch pipe discharging into the river from the west below the water company's dam, the other being a 12-inch pipe emptying into the tail race.

SEWERAGE OF BAYONNE, N. J.

GENERAL FEATURES AND CONDITIONS

Principal Topographical Characteristics. Bayonne, with a population in 1905 of 42,262, is situated on a peninsula directly south of Jersey City, from which it is separated by the Morris canal. The city is about three miles long and, as far south as Constable Hook, about three-fourths of a mile wide. It has a water frontage of over ten miles, Newark bay being on the west, Kill van Kull on south and New York bay on the east.

Bayonne is an extension of Bergen Hill, which here is fairly steep on the west side and comparatively gradual in slope on the east side; this is particularly true from about Thirtieth street north.

The natural drainage is down the streets running east and west, either way from the summits, into the bay and southeast into Kill van Kull. There are one or two exceptions to this system as laid out in the plan many years ago. The Ingram avenue and Sixteenth street sewers drain territory from some distance to the north. The land area of Bayonne is about four square miles, the water area about 2.13 square miles.

SEWERAGE WORKS

Organization for Construction and Maintenance. The City Engineer designs and constructs new sewers, which, after completion are turned over to the Street Commissioner for maintenance. The City Engineer has five civil service assistants engaged on sewer, water pipe and street improvement work. The Street Commissioner has only special appropriations for sewer work, and must ordinarily use men from the street cleaning force to clean basins and sewers.

Old System. The present combined system was designed and adopted some ten years or more ago. It is not known to-day upon just what basis the sizes were determined. It is said that many of the sewers are entirely too large for the requirements, and in consequence are not flushed at any time except during the heaviest storms.

New System. The plans for the whole peninsula are laid out on this old plan and many of the later sewers are put in larger than really necessary in conformity with the adopted plan, because it requires a good deal of time to get an amendment or ordinance of change through the Board of Aldermen, and they are loth to consider any departures from the accepted map. The general scheme is to start at the outlet with a 30-inch to 48-inch brick sewer diminishing in size to 10-inch or 12-inch vitrified pipes at the summits.

Ventilation. Manhole covers are perforated to allow free ventilation from manhole to manhole.

Outlets. The outlets for the sewers are 26 in number, 3 being into New York bay, 11 into Kill van Kull and 12 into Newark bay, located as given in Table XXVI.

TABLE XXVI
OUTLETS OF SEWERS OF BAYONNE

Location	Diameter	Drainage area ACRES	Disposal
East 47th street.....	4' 0"	150	New York bay
East 34th street.....	4' 0"	235	" " "
Avenue F.....	2' 6"	31	" " "
East 16th street.....	4' 6"	350	Kill van Kull
Ingraham avenue.....	4' 0"	245	" " "
Hobart avenue.....	1' 6"	13	" " "
Lexington avenue.....	1' 6"	8	" " "
Lord avenue.....	1' 6"	10	" " "
Avenue D.....	2' 0"	12	" " "
Avenue C.....	2' 0"	24	" " "
Humphreys avenue.....	2' 0"	9	" " "
Trask avenue.....	2' 0"	11	" " "
Rathburn avenue.....	1' 6"	8	" " "
Hudson boulevard.....	2' 0"	28	" " "
West 3d street.....	2' 0"	30	Newark bay
West 5th street.....	2' 0"	35	" "
North street.....	1' 6"	9	" "
West 16th street.....	2' 0"	18	" "
West 22d street.....	3' 0"	72	" "
West 24th street.....	1' 6"	13	" "
West 25th street.....	3' 0"	75	" "
West 29th street.....	1' 6"	8	" "
West 30th street.....	1' 6"	8	" "
West 33d street.....	3' 0"	100	" "
West 39th street.....	2' 6"	30	" "
West 59th street.....	3' 0"	65	" "

Extent of the System. The extent of the sewer system is indicated in Table XXVII.

TABLE XXVII
GROWTH OF SEWER SYSTEM OF BAYONNE

	Mileage of Sewers		Number of Outlets	Number of Basins	Number of House Connections
	Built during year	Total			
1900.....	21.	9	4,750
1901.....	....	....	..	....
1902.....	5.31	....	..	380
1903.....	....	....	..	....
1904.....	....	26.31	..	....
1905.....	.69	27.90	10	....
1906.....	.62	28.52	..	....
1907.....	.60	29.12	..	....
1908.....	2.38	31.50	25	500	

MAINTENANCE OF THE SEWERS.

Cleaning. The work of maintenance covers principally the spring cleaning of the basins down to the trap so that the water may flow out; other cleanings are given after severe storms, or upon complaint. The sewers are cleaned by hand by the maintenance force when clogged up. Contracts for cleaning certain sewers have been let at various times.

Disposal of Cleanings. The cleanings are carted to public garbage dumps on the salt meadows and covered with ashes or earth in order that no nuisance may be created.

DISPOSAL OF THE SEWAGE

Tidal Discharge. All the sewers discharge into the tide waters of New York bay, Newark bay or Kill van Kull, many of them at the bulkhead line, but some few are extended out to deep water.

Sanitary Outlets. Following complaints of nuisance there were installed at two different points house drainage outlets of 10-inch cast iron pipe carried out to deep water. A new sewer in Avenue F has also provided for the dry weather flow in the same way. Trouble has been experienced from the choking of the inlet into the cast iron pipe with sticks.

Nuisances. The residents living on the Newark bay water-front object very strenuously to the further pollution of its waters and are likely to oppose any legislation having such an object.

Future Plans. No plans have been made or studied to dispose of Bayonne's sewage otherwise than at present. As previously mentioned, the drainage plan for Bayonne has all been worked out, accepted and the greater part of it built. Disposal plants or pumping the sewage to sea are not under consideration.

SEWERAGE OF JERSEY CITY, N. J.

GENERAL FEATURES AND CONDITIONS

Principal Topographical Features. Jersey City, with a population in 1905 of 232,699, is situated between the waters of Newark bay, the Hackensack river and Penhorn creek on the west and New York bay and Hudson river on the east; it has an area of about ten square miles provided with sewerage, and is the terminus of numerous railroads, its whole Hudson river water-front being appropriated for docks.

The striking geological feature of Jersey City is the central ridge of trap about 80 feet high extending from north to south. The eastern slope drops quite sharply about one mile inland from the Hudson. The western slope breaks down somewhat less abruptly to the meadows. The ridge itself is approximately a mile in width.

The topography of Jersey City naturally requires a great many relatively short sewers emptying either side of Bergen Hill. There are no large natural water courses to indicate where best to locate the main sewers.

SEWERAGE WORKS

Old Sewers. The older sewers of Jersey City were constructed of cast iron, steel, vitrified pipe and brick. In many cases the brick sewers have had to be replaced on account of inadequacy and, in some cases, from poor construction. In the report of the State Sewerage Commission for 1900 four sewers were mentioned as being inadequate for storm service. Three of the four have since then been relieved.

The cast iron and riveted steel sewers were adopted to take care of the pressure under which many of the sewers draining the hill sections are subjected. Ten years ago there were 8.1 miles of these pressure sewers ranging from 16-inch to 66-inch diameter.

Organization for Construction and Maintenance. The Chief Engineer to the Board of Street and Water Commissioners of Jersey City has an organization of 14 men, an Assistant Chief Engineer, three assistant engineers and ten rodmen, in-

spectors, etc. These are all under city civil service regulations. It is said that the constitutionality of the civil service laws for cities of New Jersey is now under legal investigation.

Design. The engineering department of the board has charge of the design, construction and maintenance of sewers as well as of street work and water supply. The engineers and inspectors are assigned to whatever work may be on hand. All of the public work is thus correlated through the Chief Engineer.

It is the general policy to carry the combined sewage out to the water-front through numerous outlets; nearly every street running to the river has its sewer. The sections back on the hills deliver sewage to the water-front under head so that the low level sewers cannot be connected to them in many cases.

Formula. Kutter's formula for discharge is used, with $n=.013$ and a rainfall of $1\frac{1}{2}$ inches per hour is allowed for. It is apparent that this will not provide for storms of great intensity. The rains of last spring gorged practically all of the Jersey City sewers.

Materials. A great deal of the recent work has been of riveted steel and reinforced concrete construction. Vitrified tile are used in sizes up to 24-inch.

Outlets. In general the outlets discharge below low water at the bulkhead line. Practically all of the sewers emptying into the Hudson river must cross railroad property. The Carteret avenue outlet will be built out to the pierhead when the railroad fills in the land out to the established pierhead line.

The outlets of the Jersey City sewers are located as given in Table XXVIII.

TABLE XXVIII
OUTLETS OF SEWERS OF JERSEY CITY

Location	Equivalent Diameter	Size	Remarks
15th street, Hudson river.....	4' 6"	.....	Riveted Steel.
14th street, Hudson river.....	3' 5"	3' 0"x4' 0" Egg.	
13th street, Hudson river.....	5' 0"	5' 0"x5' 0" Egg.	
12th street, Hudson river.....	8' 0"	.....	Riveted Steel.
Pavonia, Hudson river.....	3' 6"	3' 0"x4' 0" Egg.	
8th street, Hudson river.....	3' 6"	3' 0"x4' 0" Egg.	
6th street, Hudson river.....	3' 3"	3' 0"x3' 6" Egg.	
2d street, Hudson river.....	4' 0"	.....

TABLE XXVIII—*Continued*

Location	Equivalent Diameter	Size	Remarks
Bay street, Hudson river.....	3' 5"	3' 0"x4' 0" Egg.	
Pearl street, Hudson river.....	3' 5"	3' 0"x4' 0" Egg.	
York street, Hudson river.....	4' 6"	4' 0"x5' 0" Egg.	
Grand street, Hudson river.....	7' 0"	.....
Essex street, Hudson river.....	3' 0"	.....
Grand street, Mill creek.....	4' 0"	.....
Grand street, Mill creek.....	6' 0"	.....	Riveted Steel.
Pine street, Mill creek.....	4' 6"	.....
Communipaw.....	.....	.....
Pine street, New York bay.....	2' 6"	.....
Carteret street, New York bay.....	two—8' 9"	.....
Richard street, New York bay.....	4' 0"	.....
Brown place, New York bay.....	5' 0"	.....
Neptune avenue, Newark bay.....	6' 0"	.....	Steel pipe.
Danfort avenue, Newark bay.....	4' 0"	.....
Swampy creek, Newark bay.....	6' 0"	.....
South Newark & N. Y. R. R., Hackensack river.....	6' 0"	.....	Not built; held up by State Board of Health.
Hatch avenue, Hackensack river.....	4' 0"	.....
Clendenin avenue, Hackensack river.....	5' 0"	.....	Steel pipe.
Communipaw avenue, Hackensack river.....	5' 0"	.....
Duncan avenue, Hackensack river.....	3' 6"	.....
Sip avenue, Hackensack river.....	4' 6"	.....
Newark avenue, Hackensack river.....	4' 6"	.....
Newark avenue, Hackensack river.....	2' 6"	.....
Van Winkle avenue, Hackensack river.....	7' 0"	.....	Steel pipe.
St. Pauls avenue, Hackensack river.....	2' 6"	.....
Manhattan avenue, Hackensack river.....	5' 0"	.....
North Bergen—Jersey City Joint, Penhorn creek.....	4' 6"	.....	Size of inlet into joint sewer at Tonnelle street.

Grades. The grades in the lower part of city are so flat that the sewage backs up some times as much as one and one-half miles. It is said that sediment does not deposit in these sewers to any extent because of the high velocities. The hydraulic grade and the grade of the invert in these sewers may not coincide.

Difficulties. The Morris canal skirts the shores of Newark bay and New York bay thereby requiring great expense for inverted siphons for all of the outlets in this territory.

The canal is in a very unsanitary condition. An inspection was made of it by the Metropolitan Sewerage Commission's inspectors from Henderson street to Mill creek on November 16th, 1909, and numerous dead animals, dead fish and quantities of garbage and ashes were observed. Bubbles were noticed rising to the surface in profusion, and green algae and slime covered the various objects on the bottom. Many out-houses overhang the canal and a small amount of sewage flow was noted near Henderson street. The canal is said to be leased to a railroad company and used only enough to hold the franchise or charter. If the canal were done away with it would clean up one of the worst appearing of Jersey City's unsanitary surroundings, and would aid the sewerage system very materially by eliminating the necessity of inverted siphons.

RELIEF SEWERS

During the last few years a number of so-called relief sewers, designed to relieve the older sewers in districts in which the old system has become inadequate, have been constructed. The following are some of these:

Division Street. The Division street relief sewer is an 8-foot riveted steel construction extending in Twelfth street from Division street to the Hudson river across the lands of the Erie Railroad Company. The cost was about \$207,500, for no portion of which was an assessment levied. The elevation of the invert is 5.9 feet below ordinary high tide so that at practically all times the top of this sewer will be exposed. The sewer serves a large low level district and there was at first connected to it a sewer draining the hill section through the New York avenue sewer. This was found to over-tax the Division street sewer at times of flood and a 54-inch steel line was built across lands of the Lackawanna Railroad Company, through Monmouth and Thirteenth streets to the Hudson river. This line runs under pressure and receives no sewage from the lower levels.

Jackson and Claremont Avenue Relief. The Bergen section, although it is situated on the hill, was subjected to flooding of streets and cellars and the Jackson and Claremont avenue relief sewer is being built to relieve it. This system outlets through an extension of Carteret avenue, with expensive crossings under the Morris canal and a great number of railroad tracks. From the foot of the hill there is an 8-foot steel pipe under the tracks; a second 8-foot concrete steel conduit has been placed alongside of the riveted steel pipe to take care of low level districts tributary north to Communipaw avenue when it shall have become built up.

Grant Avenue Relief. A 6-foot riveted steel relief sewer for the district on the hill north of Communipaw avenue has been built starting at Summit street and running down Fairmount and Grand streets to Mill creek.

Van Winkle Avenue. A 7-foot steel outlet sewer emptying into the Hackensack river at the foot of Van Winkle avenue was built to relieve the high level flow of the Newark avenue sewer.

OTHER RECENT CONSTRUCTIONS

Clendenin Avenue. A 60-inch riveted steel sewer empties into the mouth of the Hackensack river at the foot of Clendenin avenue. This drains the west side of the hill district between Communipaw and Virginia avenues.

Jersey City-Bergen Joint Sewer. A 54-inch brick sewer emptying into the joint sewer at Tonnelle street has just been completed. The joint sewer will need to be reconstructed within a comparatively short time and the expense thereof borne by both cities.

Extent of the System. Table XXIX gives some statistical data relating to the extent of the sewerage system and other matters of general interest:

TABLE XXIX
DATA RELATING TO THE SEWERAGE OF JERSEY CITY

Year	Miles of Sewers built	
	During intervening years	Total
1900.....	.....	99.5
1901.....	.....	.....
1902.....	.....	.....
1903.....	14.52	.....
1904.....	.....	.....
1905.....	.....	114.02
1906.....	.....	.....
1907.....	6.27	120.29
1908.....	2.60	122.89

Number of basins in 1900.....	1,300
Number of house connections in 1905.....	27,000
Number of factory connections in 1905.....	809
Population in 1900.....	210,000
Population in 1905.....	230,000
Number of outlets in 1905.....	23
Number of outlets in 1909.....	30
Annual expense for care, 1905.....	\$20,000

SEWERAGE OF JERSEY CITY

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Annual expense for care, 1907.....	\$27,000
Annual expense for care, 1908.....	\$26,000
Area drained, 1905, square miles.....	10
Estimated dry weather flow, 1905, cubic feet per second.....	50
Estimated stormy weather flow, 1905, cubic feet per second.....	5,000
Area of city, upland, square miles.....	13.2
Area of city, under water, square miles.....	6.0
Area of city, total, square miles.....	19.2
Paved streets, 1900, miles.....	100
Paved streets, 1907, miles.....	121.6
Paved streets, 1908, miles.....	124.9
Unpaved streets, 1900, miles.....	101.0
Unpaved streets, 1907, miles.....	80.9
Unpaved streets, 1908, miles.....	77.8

MAINTENANCE OF THE SEWERAGE WORKS

Inspection. All inspections of sewers and basins are made by a foreman and two assistants, there being no regular inspectors for the work.

Cleaning. The down town basins are cleaned about every two weeks and up town about every two months. No machines are used in the work. The cleaning of large sewers in down town districts must generally be done at low water.

The street cleaning force does not make a practice of pushing sweepings into the catch basin; nevertheless much garbage finds its way into them. Officers are instructed to arrest persons found putting anything of this sort into the basins. The streets are said to be kept quite clean.

Disposal of Cleanings. The cleanings from basins and sewers are hauled out of town to the meadows and used as filling on private holdings. No nuisance is caused as there are no houses near the dumping grounds.

Ventilation. Ventilation is accomplished through perforated manhole covers.

DISPOSAL OF THE SEWAGE

Tidal Discharge. Of the 34 sewer outfalls in Jersey City 13 discharge into the Hudson river, 3 into Mill creek, 4 into New York bay, 3 into Newark bay, 10 into the Hackensack river and 1 into Penhorn creek. All empty into the water without screening or purification of any kind; nuisances are common. The following are the general conditions attending the discharge at different localities:

Hackensack River. There is said to be no nuisance caused by sewers emptying into the Hackensack river at Jersey City because of the swift current and deep water.

Penhorn Creek. Penhorn creek is badly polluted by the Jersey City-North Bergen joint sewer. Notice from the State Sewerage Commission to Jersey City and West

Hoboken to cease polluting Penhorn creek prior to May 1, 1908, was disregarded. The Attorney General was requested to bring proceedings against these two municipalities to enforce the notice.

Newark Bay. Bayonne complains that the sewers emptying into Newark bay from Jersey City pollute her shores.

Hudson River. The sewage emptying into the Hudson river at the bulkhead line between the various piers of the railroad companies may easily be noted. It has not the chance to be diluted, digested and carried away that it would have were it delivered to the ends of the piers.

Mill Creek. An inspection was made of this creek from the Morris canal to Grand street on November 16, 1909. The creek is an open sewer. The odor was quite noticeable.

A 6-foot riveted steel pipe and two 4-foot cast-iron outlets were each running about half full of sewage of a comparatively fresh character. The current in the creek is fairly rapid and the channel well defined, so that the sewage is carried away rapidly.

Mill creek also receives sewage from a 4-foot 6-inch sewer emptying at the foot of Pine street.

Future Plans. No future plans for the disposal of the Jersey City sewage have been formulated, or even talked of, except in a general way; it is conceded, however, that a system different from the present one of draining into the nearest available water must be devised at no distant date.

Mr. Emil Kuichling, M. Am. Soc. C. E., has, at various times, passed on plans and advised in a general way on the design and construction features of various projects as they have been developed.

Greenville. A district of about 150 acres in the Greenville section is now needing sewers. A system has been designed with an outlet into Newark bay, just south of the Newark and New York railroad, but the State Board of Health has refused to allow it to be built, or in fact any other to discharge into Newark bay, without first removing "the solid material" therefrom. The Board of Street and Water Commissioners is now considering what to do to comply with these regulations. No designs for a purification plant are being studied.

Grand Avenue. It is proposed to build an extension of the Grand avenue sewer up Grand avenue from Fairmount avenue to Park avenue to relieve the tributary district; there is also a plan to build an extension of the outlet in the bed of Mill creek to the basin and fill up Mill creek its entire length.

SEWERAGE OF HOBOKEN, N. J.

GENERAL FEATURES AND CONDITIONS

Principal Topographical Features. Hoboken city, with a population in 1905 of 65,468 has an area of about 720 acres served with sewers, and lies just north of Jersey City; various railroad lines bound it on the south, east and north, and the Hudson river on the west.

The main topographical feature of Hoboken is Stevens Point rising to a height of 100 feet quite near to the Hudson river and sloping landward in all directions. The northeastern portion of the city is still unfilled swamp. Practically all of the sewers are built on piles. No rock is encountered in making excavations.

Naturally, since the surface drains away from Stevens Point in all directions, but two general drainage districts are possible. The first drains practically all the streets from about Ninth street to the south into interceptors running down Third, Newark and Ferry streets to the river. The second general system drains a smaller area to the north of Eighth and Ninth streets in a similar way through Eleventh and Fourteenth streets to the river.

SEWERAGE WORKS

Design of Sewers. The design and construction of new sewers is done by a civil engineer designated by the Board of Aldermen, for the particular work in question.

Very little information is obtainable regarding the design and construction of the Hoboken sewers. There has been no work of magnitude carried on in recent years.

Old System. All the sewers in Hoboken are on the combined system. An official map is on record in the City Clerk's office showing the sewers. On this map three wooden box sewers, said to be 8 feet square, are shown emptying into the canal in the Delaware, Lackawanna & Western R. R. yards. A 4-foot wooden box sewer is shown emptying into a small basin near the foot of Fifteenth street. The outlet of the sewer and also that of the basin are shown with automatic gates. One of these old box drains, which has been replaced within the last few years, was found in an excellent state of preservation as it had been completely submerged at all times. The remaining sewer outlets shown on the official map are of brick construction.

Outfalls. The sewer outfalls are given in Table XXX.

DATA COLLECTED

TABLE XXX

OUTFALLS OF HOBOKEN, N. J., SEWERS

Description	Size	Elevation Outlet—Invert Feet	Area Drained; Acres	Remarks
Provost street.....	8'x8'	—15.0	....	Wooden box
Park avenue.....	8'x8'	—5.8	....	Wooden box
Bloomfield street.....	8'x8'	—7.67	....	Wooden box
Ferry street.....	4'x8'	....	110	
Newark street.....	2'6"x4'0" Egg.	—8.9	....	Brick
Newark street.....	5'0"	....	45	
3rd street.....	5'0" diam.	—6.1	225	Brick
11th street.....	4'0"x2'6" oval	—1.5	125	Brick
14th street.....	2'4"x3'6" Egg.	—3.3	50	Brick
15th street.....	4'0"x4'0" square	....	....	Wooden box

Notes.

Elevations refer to mean high water.

The Provost street, Park avenue and Bloomfield street outlets discharge into a long ship canal extending inland from the Hudson river. All the other sewers discharge into the Hudson river either in ferry or steamer slips or at the bulkhead line.

Extent of the System. In 1905 there were about 15 miles of sewers in Hoboken, with 4,300 house connections. There were 1,300 catch basins connected with the system in 1900. The total area drained by the sewers is 1.1 square miles.

MAINTENANCE OF THE SEWERAGE WORKS

The Street Commissioner has charge of the maintenance of the sewers, for which purpose he has two gangs consisting of three men and a cart each.

Inspection. No regular inspections are made of basins and sewers.

Cleaning. It is said that the basins are cleaned three or four times per year, and the sewers when they fail to work. Rods are pushed through from manhole to manhole and then a rope with buckets attached to it is drawn through by means of a windlass. This method can be used when the sewer is full of water.

Disposal of Cleanings. The basin and sewer cleanings are taken to the meadows and used as filling. The dumping places are too far from houses to give rise to complaints.

DISPOSAL OF THE SEWAGE

Tidal Discharges. All the sewers discharge into tide water of the Hudson river without treatment or purification.

Tide-locked Sewers. The inverts of the outlets, with the exception of those of the Eleventh and Fourteenth street sewers, are all tide-locked at high water.

The following extract from the 1905 State Sewerage Commission Report, page 182, describes this condition.

"The sewerage system for the lower meadow section is based on the tidal system. The outlets are provided with sluice gates, which are raised and lowered at the change of the tides by a service gate keeper. A few of the sewers coming from the higher section do not require sluice gates; a system of drainage by pumping has been under consideration for some time, but no definite action has been taken towards its establishment."

Nuisances. Complaints have been made to the State Board of Health of New Jersey of a nuisance caused by the Newark street sewer outletting into a basin formed by the piers of the Hamburg-American Steamship Company and the Lackawanna Railroad. An inspection made by Board of Health found "that the sewage had a tendency to remain near the end of the pipe until putrefied and became a nuisance to the neighborhood." At an inspection by an inspector of the Metropolitan Sewerage Commission on November 19th, 1909, practically the same conditions were observed. Bubbles of gas were noted rising to the surface, through the grayish colored water which gave off a distinctly sewage odor. The Hamburg-American Steamship Company has lodged complaint with the city Board of Health and the Mayor of Hoboken but no action has been taken. Owing to the fact that the city's sewers discharge into the Hudson over private property "It was stated that there is a legal question involved as to who shall remedy conditions existing at present."

Future Plans. There have been a number of plans and studies made of the sewerage problem in Hoboken by Mr. T. H. McCann, as well as other consulting engineers, but no definite action has been taken with respect to further improvements in sewerage. An installation of pumps to drain the tide-locked sewers and do away with the intermittent discharge has been proposed.

SEWERAGE OF THE RAHWAY RIVER VALLEY

GENERAL FEATURES AND CONDITIONS

Principal Topographical Characteristics. The watershed of the Rahway river and its tributaries lies to the east and southeast of the Elizabeth and Morse creek watersheds, and to the south of the Passaic watershed.

It covers an area of 250 square miles and drains a large tract of swampy land to the east of Rahway characterized by numerous small lakes. The land drained

up to about 12 miles from its mouth is comparatively flat. At this point it branches either side of First Watchung Mountain whose slopes are very steep.

Municipalities on the Watershed. A list of the various municipalities, with a total population in 1905 of over 45,000 people living on this watershed, is given in Table XXXI.

TABLE XXXI
MUNICIPALITIES IN RAHWAY RIVER WATERSHED

City	1905 Population	Remarks
Rahway	8,649	Must cease polluting by November 1, 1911
Rahway Reformatory.....	538	
Clark	387	
Fanwood Township	1,341	
Cranford Township.....	3,600	Must cease polluting by November 1, 1911
Garwood.....	564	
Westfield	5,265	Have disposal plant
Springfield Township	1,123	
Millburn Township.....	3,182	Drain into Joint outlet
Summit.....	6,845	Drain into Joint outlet
West Orange.....	7,872	Drain into Joint outlet
South Orange.....	4,932	Drain into Joint outlet
South Orange Township.....	1,946	Drain into Joint outlet
	46,244	Total
	24,777	Drain into Joint outlet
	21,467	Drain into Rahway

SEWERAGE WORKS OF THE MUNICIPALITIES

Rahway. Rahway, with an estimated population in 1905 of 8,649, is the largest city on the watershed. Its sewage is discharged into the Cranford-Rahway trunk sewer, which in turn discharges into the Rahway river below the city of Rahway. This sewer is the only one noted as polluting the Rahway river below the water works intake, but the stream is small and consequently is badly polluted.

In 1906 Rahway complained to the State Sewerage Commission that the trunk sewer from Cranford was overflowing in the streets of Rahway. Cranford replied that by agreement Rahway was to care for that portion of the sewer lying in Rahway, and

the outlet, and that therefore Cranford was not responsible. It would seem from this that the sewer was not of sufficient size at this time or else the capacity has become reduced from sediment.

Rahway was notified by the State Board of Health to cease polluting the river by November 1, 1911.

Rahway Reformatory. In 1901 plans for a 50,000 gallon disposal plant were drawn and the work partly constructed. They have never been completed and during all this time raw sewage has been discharged down Woodbridge road through a 10-inch pipe into the river. In 1908 Waring, Chapman and Farquahar drew plans for this plant and included an electric pump, screen chamber and sand filter beds. The first design was not acceptable to the State Sewerage Commission and after revision the bids submitted for its construction were higher than the appropriation. The Commission then requested Prof. E. B. Phelps to devise a plan and he recommended chemical disinfection and septic action. Owing to the danger of the pollution of shellfish this method of treatment was considered the only one available. A 10-inch pipe was considered ample for house sewage for a great many years to come and an 18-inch pipe recommended to care for storm water. The adoption of separate systems was urged by Prof. Phelps.

Cranford. Cranford township has a population of about 3,600 and, as above stated, it sewers into the trunk emptying below Rahway. It has about ten miles of sewers on the separate system. In 1902 and 1905 a citizen of Cranford complained of various factories on the river above. Inspections were made and notices to cease pollution were served by the State Sewerage Commission, but it was not considered possible to make the water potable. In 1900 there was reported a water consumption of but six gallons per capita per day and with a population of 2,800 there was estimated a daily sewage discharge of but 20,000 gallons. Ten per cent. of the sewage was estimated to be ground water.

Garwood. A plan to extend the Cranford system out through Garwood has been made and was in the process of construction in 1908. A private sewer 6,000 feet long draining the overflow of cesspools is to be connected up with the new system.

Westfield. Westfield's system was built in 1895. At that time 12 miles of sewers were laid, but the system has since been extended to about 15 miles. The present system had 974 connections in 1908 and cared for about 6,000 people. The volume of sewage was estimated at 400,000 gallons daily. The sewers leak badly and in rainy weather the quantity may be doubled on this account.

There is a sewage disposal farm of 108 acres about two miles from town. Twelve acres are available for the disposal plant, which consists of a double screen chamber,

three sludge beds, a septic tank, five intermittent filter beds and four irrigation tracts. The effluent runs into a small stream which is caught by a large iron main and conducted about two miles and emptied below the intake of the Rahway water works.

Millburn Township. Millburn Township had 15 miles of sewers in 1905, with about four miles planned. It is connected with the Joint outlet sewer emptying into Staten Island Sound. The territory of 2,800 acres drained had in 1905 a population of 3,500 living in 350 houses. There were three paper mills using 6,000,000 gallons of water daily. The separate system is cleaned by automatic flush tanks. It costs \$500 per year to care for the system. This township, it is to be noted, does not pollute the Rahway river.

Summit. Summit lies on the ridge between the Rahway and Passaic rivers. It had an estimated population in 1908 of 8,000. It produces about 500,000 gallons of sewage daily, all emptying into the Joint outlet sewer. The whole town is sewered. About half of the sewage runs by gravity and the remainder must be pumped over the ridge. There is an abandoned sewage disposal plant for the portion now pumped. The sewage of Summit is taken out of its natural watershed into that of the Elizabeth river.

Orange. In 1900 about 500,000 gallons of sewage daily produced in the city of Orange from 280 acres in the Rahway valley was pumped over into the Passaic valley. There still exists an old sewer discharging into the Rahway, used for storm overflow, into which house connections were made; complaints have been made of this by South Orange. The State Sewerage Commission found in 1906 it had no jurisdiction over cities within the district of the Passaic Valley Commission. In 1907 the overflows from the regular sewers of Orange to the storm water outlet into the Rahway were disconnected and the private connections into the storm water drain also cut off. Factory wastes still discharge into the sewer to some extent. A number of private sewers from hat factories and others still discharge into the stream, and notices were sent to some dozen different parties to cease polluting the river.

West Orange. West Orange lies to the east of the First mountain at the head waters of the east branch of Rahway river and the Second river. Practically all of its area, 2,325 acres tributary to the Rahway is sewered into the Joint outlet sewer.

Union Township. A portion of the area of Union Township lies in the Rahway watershed, but there are no towns of any size within its limits.

South Orange Township. Plans for the township of South Orange to discharge its sewage into the Joint outlet sewer were approved September 12, 1907. South

Orange Township through an arrangement with South Orange village has a right to use the Joint outlet. It has a territory of about 3,754 acres.

South Orange. South Orange is situated on both sides of the river just to the east of First mountain. It has an area of 1,575 acres and a population of about 5,000. Its sewers drain into the Joint outlet.

Factories. A large number of various kinds of factories pollute the Rahway river; these have been served many times with notices to cease the pollution and promises to stop were freely given each time, but little was done. It is probable that the injury to fish and shellfish is due to the factory pollution to a much larger extent than the house sewage proper.

CHAPTER VI
FOULING OF THE BEACHES OF LONG ISLAND AND NEW JERSEY
BY GARBAGE WASHED UP FROM THE SEA
DURING THE SUMMER OF 1906.

SECTION I
RESULTS OF INSPECTIONS

COLLECTION OF INFORMATION

Purpose of Investigation. Following is the substance of a report sent to Mayor McClellan in answer to a request from Acting Mayor McGowan in July, 1906, that the fouling of the Long Island and New Jersey shores with garbage be investigated. The presence of so much garbage was exceptional. It was found to be due to the fact that the garbage of the City of New York was being dumped at sea in order to dispose of it until the Barren Island disposal works, which had recently been destroyed by fire, could be rebuilt.

The information contained herein relates to the circumstances under which garbage was found on the beaches with respect to the places where it was washed up, the force and direction of the wind, stage of the tide, quantity of garbage, the composition and condition of the garbage with reference to decomposition, the measures which it was necessary to take to remove the garbage from the beaches, the location of the places at sea where the garbage was dumped, the quantities of garbage dumped each day, and the rate at which the garbage was driven by the wind through the sea.

Usefulness of Data. These data are of interest not only because sea dumping may at some time again be necessary, but because the behavior of this garbage gives an idea of the course which sewage might take if emptied under similar conditions at the mouth of the harbor.

Organization of Inspection. The inspection of the shores of Long Island and New Jersey began July 10, 1906, and were continued until the 15th of August of the same year. A large part of the work was done by a Chief Inspector of the Metropolitan Sewerage Commission assisted by six or eight volunteer inspectors at carefully selected points on the two lines of coast. Most of these volunteer inspectors were bathing masters or life guards, whose occupations kept them on the beaches continually. At the beginning all were shown how to keep systematic records of their observations. In this way it was found feasible to watch the Long Island shore as far east as Westhampton, about 80 miles from New York, and the New Jersey coast as

far south as Atlantic City, about 90 miles from New York. These inspections were supplemented by observations made by members of the United States Life Saving Service.

In order to observe the behavior of the garbage in the sea and to make observations concerning the speed at which it was carried by currents two days were spent by one of the members of the Metropolitan Commission on the ocean, the distance covered in these two days having been about 160 nautical miles.

Records of the force and direction of the principal prevailing winds since the beginning of the investigations were supplied by the United States Weather Bureau. The Department of Street Cleaning of the City of New York furnished records of the amount of garbage, in loads and tons, dumped at sea each day, and indicated the points where it directed that the dumping be done. The Supervisor of the Harbor explained the system by which he sought to prevent the dumping of garbage inside the three-mile limit.

SUMMARY OF INFORMATION COLLECTED

The information collected may be summarized as follows:

Dumping Grounds and the Effect of Changing their Location. At first the dumping grounds were at a point about 17 miles from Seabright, N. J., and 18 miles from Long Beach, L. I.; their removal to a point about 25 miles from Seabright and about 17 miles from Long Branch on August 17 lessened, but did not remove, the risk of fouling the New Jersey beaches.

Effects of Winds on Travel of Garbage. During the periods when garbage was dumped at sea the New Jersey and Long Island beaches were befouled whenever a brisk wind blew shoreward from the ocean. When calms or light winds occurred the garbage accumulated until a favorable wind occurred to carry it to shore.

Fields of Floating Garbage. Inspections of the sea in all directions to a distance of about 35 miles from the Narrows showed in calm weather the presence of fields of many acres of garbage, even after dumping had been entirely suspended for two days.

Rate of Travel of Garbage toward Beaches. Accurate observations at sea showed the garbage traveling toward shore at a rate of over one-half a mile per hour when the tide was favorable and the wind blowing landward at a rate of about five miles per hour.

Return of Floating Garbage to New York Harbor. Under the action of continued easterly winds some garbage originally dumped at sea about 15 miles beyond the entrance to the Gedney channel returned to New York and was thrown upon the Staten Island beaches about 29 miles away. A small amount actually entered the Narrows and was driven into Upper New York bay.

Distances Traveled by Garbage. Garbage was at times found on the Long Island beaches as far east as Smiths Point, near Center Moriches, 50 miles from the dumping

grounds; on the New Jersey shore as far south as Atlantic City, 76 miles from the dumping ground; and on the Staten Island shore, about 25 miles from the dumping ground. All the seaside resorts between these points and New York were inconvenienced to a greater or lesser extent by the dumping of New York City garbage at sea.

Pollution of Long Island and New Jersey Beaches with Garbage. Most of the garbage which polluted the beaches of Long Island and New Jersey was unquestionably garbage from the City of New York which was dumped at sea. Steamers and other vessels were capable of furnishing but a very small part of the total amount of garbage which polluted the ocean shore.

Quantity of Garbage on Beaches. The quantity of garbage deposited on the beaches varied from an amount which scarcely caused objection to an amount which drove bathers from the water. There was found, on one occasion, on the New Jersey beach below Ocean Grove, one cubic foot of garbage on each 100 square feet of beach for a considerable distance.

Winds of Summer of 1906 Favorable to Small Deposits. Meteorological records showed that July, 1906, was an unusually favorable month for the disposal of garbage in the manner followed because of the comparative infrequency of landward breezes of considerable velocity. Had normal winds prevailed the beaches would have been in a more objectionable condition.

Loss of Offensiveness Due to Immersion. The garbage which was washed ashore after many hours was not of the same composition nor in the same condition as when dumped at sea. It was, for the most part, less offensive. Much of the heavier solid matters had sunk.

The vegetable matter, from its immersion, was deprived of its most objectionable qualities and was offensive chiefly to the eye. Of that portion of the garbage which was carried to shore, the most offensive elements were dead and decomposing animals, such as dogs, cats, rats and fowls.

Grease, which was washed upon the beaches in lumps varying in size from particles as large as peas to pieces of a pound or more in weight, was particularly objectionable to bathers, but did not give rise to offensive odors. Wood, which was often washed upon the beaches in quantity and was mostly from other sources, was carefully distinguished from garbage in this investigation.

Control of Future Sea Disposal When Again Necessary. For the proper protection of the New Jersey and Long Island beaches in future, it is recommended that the dumping of garbage from passing ships be restricted as far as practicable especially in the months of June, July and August.

If necessity ever again requires that the garbage of New York be dumped at sea it should be transported in sea-going ships and carried at least 100 miles from the Gedney channel whistling buoy.

SECTION II

INSPECTIONS BY METROPOLITAN SEWERAGE COMMISSION

THE SHORES OF LONG ISLAND

WESTHAMPTON AND SMITH POINT BEACHES

Westhampton Beach, Long Island. August 3rd, 11.30 a. m. Wind, southeast, fresh. Tide, high, rising. Shore very clean. Some seaweed and driftwood. A few corks and bottles. No garbage along shore. Local observer states that no garbage came ashore there July 29 or 30 and that he has seen none there this season.

Smiths Point Beach near Center Moriches. August 3rd, 4.00 p. m. Wind southeast, fresh. Tide low, falling. Small amount of garbage along the shore. The local observer on this beach states that he had noticed very little garbage on this beach this season, but that some had come up on July 29 and 30. There had not been so much this summer as in former seasons.

Summary. The southwest wind on July 29 and 30 washed garbage on Smiths Point beach off Center Moriches but no further east, so far as could be learned by personal investigations and report.

OPPOSITE PATCHOGUE

Water Island off Patchogue, L. I. August 4th, 1906, 11.00 a. m. Wind southwest, fresh. Tide high. About the same quantity of garbage here as at Smiths Point beach. Easily distinguished but hardly enough to estimate. Bathing master reports no trouble from garbage this season. Did not see this come ashore, he said.

Summary. Small quantity of garbage on beach of Water Island; probably there since July 29 and 30 southwest winds.

OAK ISLAND

Oak Island, West of Fire Island. July 17, 1906, 3.00 p. m. Wind, southwest, strong. Tide, three-fourths full, rising.

Oak Beach. Shore opposite first steamboat landing toward Fire Island. Considerable seaweed and some driftwood on the shore. One-half cubic yard seaweed in 400 square feet. No garbage on shore or in water. Shore never cleaned except of driftwood for fuel. Observer said he had seen no garbage on the shore this season.

Shore of Oak Island at United States Life Saving Station. Near western end of Island. July 17, 4.00 p. m. No garbage. Seaweed and driftwood only.

FIRE ISLAND AND OAK ISLAND

Fire Island from bathing beach opposite hotel west to Life Saving Station and east toward Point o' Woods. July 31, 11.00 a. m. to 3.00 p. m. The wind, light from the west. Tide full at 4.00 p. m.; rising.

Garbage all along this beach which came ashore Sunday and Monday with southwest wind. The decayed vegetables comprised apples, oranges, lemons, pineapples, onions, turnips, potatoes, banana skins, corn, watermelon, squashes and cabbages. Also many pieces of fat meat and grease, pieces of bread, seaweed and driftwood. Also dead animals. Observer stated that beach was cleaned Sunday morning and that Sunday afternoon and Monday a large quantity of garbage came ashore. Estimated quantity of garbage on shore, one-half cubic foot on 400 square feet of beach.

Oak Island. A good deal of garbage came ashore on Oak Island on Sunday and Monday, July 29 and 30; also many crates of fresh lemons.

Summary. Considerable amount of garbage on Fire Island and Oak Island shores blown there with southwest winds on July 29 and 30.

LONG BEACH

Long Beach Bathing Beach. July 12, 1906, 11.45 a. m. Wind, southeast, light. Tide, high, rising. In 400 square feet of shore was one-half cubic yard of vegetable matter, mainly seaweed with some driftwood and shells. Quantity was estimated from one side of bathing beach as beach was cleaned. No garbage on shore or in water. Observer says he has seen no garbage on shore since July 1st, and that during the last week in June the beach was filthy with decayed vegetables, presumably from New York dumping scow. None seen since then, even after south winds.

Long Beach Bathing Beach. July 30, 1906, 11.15 a. m. Wind, southwest, fresh. Tide, one-half high, rising. Large amount of garbage, driftwood and seaweed came ashore on this beach yesterday during strong northeast wind and considerable is coming ashore to-day, although less than yesterday, as wind not so strong. Observer said more garbage came ashore yesterday than at any time since June. Said that considerable came ashore about the 18th or 19th with a southwest wind. Besides garbage he buried two dead cats and several rats yesterday. Said that fifteen or twenty crates of good lemons were picked up on the beach yesterday P. M.

Shore to West of Inn. July 30, 1906, 12.25 p. m. Wind, southwest, fresh. Tide, high, rising. All along shore a large quantity of decayed vegetables of various sorts, pieces of fat meat, of bread, besides driftwood, seaweed, bottles, tin cans, straw, paper, corks, feathers, etc. Amount of garbage about 1½ cubic feet

in 400 square feet. Amount of seaweed and driftwood about 2 cubic yards in 400 square feet.

Shore to Pt. Lookout Life Saving Station. July 30, 1906, 2-4.15 p. m. Wind, southwest, fresh. Tide, full about 3. Large quantity of decayed vegetables, many pieces of fat meat, bread, a dead fowl, seaweed, driftwood, mattress, bed, tin cans, straw paper, horse dung, bottles and brushes. About one and one-half cubic feet garbage in 400 square feet. About two cubic yards seaweed and driftwood in 400 square feet.

Summary. Large amount of garbage all along South Beach shore, blown ashore by southwest winds yesterday and to-day.

ROCKAWAY BEACH TO CONEY ISLAND

Rockaway Beach. July 11, 1906, 9.40 a. m. Wind, northeast, light. Tide, high, rising. In 400 square feet of shore was one-half cubic yard vegetable matter, practically all seaweed with some driftwood. No odor. No garbage or sewage seen in water or on shore except as noted above. Guard says there has been no trouble this season from garbage coming ashore even after strong south winds. Said that people who live along the shore dump their garbage on the shore at night, which would account for what is found.

Seaside Boat Landing on Rockaway Inlet. July 11, 1906, 10.30 a. m. Wind, northeast, light. Tide, high, rising. Guard on beach above reported complaints of garbage coming up into inlet, during south wind. Men interviewed, said garbage floated up into Jamaica bay after a south wind. Saw none myself. Only seaweed.

Far Rockaway. A leading bathing place. July 11, 1906, 11.45 a. m. Wind, northeast. Tide, high, full. In 400 square feet shore one-fourth cubic yard vegetable matter; mainly seaweed, some driftwood. No odor. No garbage in water or on shore except as above noted. Guard says there has been no trouble this season from garbage coming ashore even after strong south winds.

Manhattan Beach. July 11, 1906, 2.30 p. m. Wind, south, light. Tide, high, falling. In 400 square feet of shore one-eighth cubic yard vegetable matter. No garbage on beach or in water. Heard reports in Rockaway that this beach was polluted with garbage but found that the seaweed only caused the trouble. No garbage has been seen on the shore this season to speak of, even after several days of southerly winds, according to the life guards at the bathing beach. They said it was not so bad as in former years.

Brighton Beach. Bathing shore east of Brighton Beach Hotel. July 11, 1906, 3.30 p. m. Wind, south, light. Tide, half high, falling. Shore clean except for seaweed. No garbage seen on shore or in water. One guard says there was a good deal of garbage on the shore after south winds in June. Had not seen it since, except on Saturday last, when there was some in the water.

A Leading Bathing Place. July 11, 1906, 3.50 p. m. Wind, south, light. Tide, half high, falling. Shore quite clean. No complaint of garbage in water this season according to guards.

Coney Island. A principal bathing point. July 11, 1906, 4.30 p. m. Wind, south, light. Tide, low, falling. Shore clean. No garbage to any extent this season. Banana skins and orange peels thrown on beach by bathers. Shore cleaned every morning, as are other shores noted above, and scarcely anything but seaweed and driftwood found in rakings; even after strong south winds.

Summary. Practically no garbage on Rockaway or Coney Island shores.

ROCKAWAY POINT TO HOLLAND

Rockaway Park. Shore of Rockaway inlet, foot of Fifth avenue. July 18, 1906, 10.20 a. m. Wind, southwest by south. Tide, low, rising. No garbage on shore nor in water. Sewage on water and shore from sewers emptying nearby.

Belle Harbor. Rockaway Park near Life Saving Station. South shore. July 18, 1906, 11.30 a. m. Wind, southwest by south. Tide, low, rising. In 400 square feet of shore 8 cubic feet vegetable matter, mainly wood and seaweed.

Rockaway Park. Popular bathing beach. July 18, 1906, 1.10 p. m. Wind, southwest by south. Tide, half high, rising. In 400 square feet of shore 4 cubic feet vegetable matter, mainly driftwood and seaweed.

From Sea Beach House, Seaside to Iron Pier. July 18, 1906, 2.20 p. m. Wind, southwest by south. Tide, half full, rising. Large quantity of corn husks and imperfect ears of corn. Averaged 1 cubic foot in 400 square feet of shore. Undoubtedly thrown into water at this beach early this morning as they were not much decayed nor much water soaked, and practically no other garbage seen with them except a few decayed vegetables.

Rockaway Beach. July 18, 1906, 3.45 p. m. Wind southwest by south, light. Tide, three-fourth full, rising. No garbage on shore. Shore kept clean. Observer says no garbage worth mentioning has come ashore this season.

Large Hotel, Holland, Rockaway Beach. July 18, 1906, 4.20 p. m. Wind, southwest by south. Tide, three-fourth full, rising. Seaweed and driftwood seen on bathing beach to slight extent.

Summary. Shore of Rockaway Beach shows little evidence of decayed garbage. The history is practically negative. Wind was light. It would have been more favorable for garbage on shore if south.

HAMMELS TO SEASIDE

Hammels Station, Rockaway Beach. July 24, 1906, 10.15 a. m. Wind, northeast, light. Tide, full, falling. Along 200 feet of shore in space 20 feet back from water, decayed vegetables, pieces fat meat, corks, paper, cloth and straw. Seaweed and driftwood. In 400 square feet (20 x 20) about one-half cubic foot garbage.

Shore Between Hammels and Arverne. July 24, 1906, 11.10 a. m. Wind, northeast, light. Tide, high, falling. Same as above, average one-half cubic foot garbage in 400 square feet up to beach controlled by Arverne Association. This cleaned every morning by Italians. Near Hammel was cigar store Indian, a bed and a trunk.

Arverne Beach. July 24, 1906, 11.30 a. m. Wind, northeast, light. Tide, high, falling. Shore kept clean by guard. Observer says garbage in considerable amount comes ashore after south wind of a day or two.

Shore Between Arverne and Edgemere. July 24, 1906, 1.10 a. m. Wind, northeast, light. Tide, half low, falling. Considerable garbage all along shore. All sorts of decayed vegetables and pieces of fat meat. In 400 square feet (20 x 20). Average, 1 cubic foot. Garbage, all decayed and evidently from dumping scows. Also bottles, tin cans, mattresses, seaweed, driftwood, corks, etc.

Bathing Beach Near a Much Frequented Club. July 24, 1906, 2.05 p. m. Wind, northeast, light. Tide, low, falling. Shore kept clean by guard.

Beach Between Edgemere and Far Rockaway. July 24, 1906, 3.15 p. m. Wind, northeast, light. Tide, low, ebb. Considerable garbage along shore. In 400 square feet about one cubic yard.

A Bathing Beach, Far Rockaway. July 24, 1906, 4 p. m. Wind, northeast, light. Tide, low, rising. Beach kept clean. Very little garbage seen.

Bathing Beach, Seaside, Rockaway Beach. July 24, 1906, 5.05 p. m. Wind, northeast, light. Tide, low, rising. Found man dumping garbage on top of pile of refuse to be burned. Said it was the customary thing here. Good deal of fresh garbage between sea and boardwalk. Had not been in water.

Summary. Considerable garbage where shore is not kept clean for bathing. Decayed vegetables, bread, fat meat, etc., brought in by the southerly winds of the past few days. Odor not objectionable.

BRIGHTON BEACH TO MANHATTAN BEACH

Brighton Beach. July 16, 1906, 1.35 p. m. Wind, south by southeast, fresh. Tide, half full, rising. In 400 square feet of shore 16 square feet of vegetable matter, mainly seaweed, very little driftwood. Considerable garbage constantly being deposited on shore and cleaned off every 15 or 20 minutes.

Shore Near Manhattan Beach. July 16, 1906, 2.40 p. m. Wind, south by southeast. Tide, half full, rising. Water noticeably full of garbage for some distance east of Brighton Beach.

Manhattan Beach. July 16, 1906, 3.25 p. m. Wind, south by southeast. Tide, nearly full, rising. Shore not so much polluted as at Brighton as tide carries it toward that point and wind not so favorable. In 400 square feet of shore six square feet seaweed and some driftwood and decayed vegetables. This beach also partly protected by sand bar just east of Oriental Hotel. Guard says that on Saturday with a southeast wind there came ashore in addition to some garbage the following dead animals: 1 black cat, 1 (5 lb.) chicken and 3 rats.

Manhattan Beach, Baths to end of Point beyond Oriental Hotel. July 16, 1906, 4.40 p. m. Wind, south by southeast. Tide, full, falling. Less garbage noted in water along bulkhead than west of Manhattan Beach, apparently because of direction of wind, the tide and the sand bar.

Summary. Shores of Brighton Beach and Manhattan Beach, with the wind south by southeast and rather fresh, favorable for garbage being carried to these shores from alleged point of discharge; are in rather bad condition. Considerable garbage found on shore, although beaches were being constantly cleaned. All vegetables much decayed and water soaked.

SEA GATE TO WEST BRIGHTON

Sea Gate. Nortons Point. July 14, 1906, 10.15 a. m. Wind, southeast, fresh. Tide, half full, rising. In 400 square feet of shore one-eighth cubic yard vegetable matter, mainly driftwood, with some seaweed. No decayed vegetable matter or sewage on shore or in water.

Sea Gate Beach. *Nortons Point to Entrance of Sea Gate Association.* July 14, 1906, 11.20 a. m. Wind, southeast, fresh. Tide, half full, rising. Less driftwood than at the point. More seaweed. No garbage or sewage on shore or in water. Observer said since July 1 the shore has been quite free from garbage, even after south winds; that during June same came ashore, being especially bad on foggy day; 17 dead animals landed.

A Popular Hotel Near Sea Gate, Coney Island. July 14, 1906, 1.05 p. m. Wind, southeast, fresh. Tide, nearly full, rising. Shore clean except for shells; some seaweed and driftwood. No garbage seen.

Sea Gate Beach Near West Brighton. July 14, 1906, 1.50 p. m. Wind, southeast, fresh. Tide, nearly full, rising. Only seaweed and driftwood, one-eighth cubic yard in 400 square feet of shore.

Coney Island. July 14, 1906, 2.45 p. m. Wind, southeast, fresh. Tide, full, falling. Seaweed and driftwood. Shore very clean. Observer says he has noticed very little garbage on shore this season.

A Leading Amusement Center, Coney Island. July 14, 1906, 3.35 p. m. Wind, southeast, fresh. Tide, full, falling. Shore clean; no trouble since July 1.

A Popular Bathing Beach, Coney Island. July 14, 1906, 4.20 p. m. Wind, southeast, fresh. Tide, half full, falling. Banana peels, orange peels, etc. (not decayed), thrown by bathers on shore. No trouble except from seaweed and sea shells.

Summary. No garbage to be seen on shores of Sea Gate or Coney Island.

CONEY ISLAND AND MANHATTAN BEACHES

Coney Island. August 1, 1906, 10.20 a. m. Wind, southeast, light. Tide, low, rising. No garbage on beach except few pieces of grease and bread.

A Popular Bathing Beach. August 1, 1906, 11.15 a. m. Wind, southeast, light. Tide, low, rising. As above.

Brighton Beach. August 1, 1906, 1.10 p. m. Wind, northeast, very light. Tide, low, rising. Few pieces of grease, 1 decayed tomato, 1 apple. Nothing else but seaweed and a little driftwood. Local observer says that they have had no garbage on this beach worth mentioning for some time, that on July 29 and 30 a very little came ashore.

Manhattan Beach. August 1, 1906, 2.35 p. m. Wind, northeast, light. Tide, one-half high, rising. No garbage on shore except few pieces of grease in the sand.

Along Neckwater Beyond Oriental Hotel. August 1, 1906, 3.20 p. m. Wind, northeast, light. Tide, three-fourths high, rising, full 5 p. m. No garbage seen in water.

Summary. Coney Island shore very free from garbage.

THE SHORES OF STATEN ISLAND

SOUTH BEACH AND MIDLAND BEACH

South Beach, Staten Island. July 13, 1906, 10.10 a. m. Wind, east, moderate. Tide, half full, rising. In 400 square feet of shore one cubic yard vegetable matter, mainly driftwood with some seaweed and decayed vegetables. Quite a quantity of

decayed vegetable matter brought ashore by east wind, evidently from dumping scows. Guard says it was worse last Friday and Saturday. No particular odor, except from dead turkey and fish.

Along Shore from South Beach to Midland Beach. July 13, 1906, 11.30 a. m. Wind, east. Tide, half full, rising. Practically the same as above except a great amount of driftwood as beach not cleaned as are bathing beaches.

Midland Beach, a Leading Bathing Beach. July 13, 1906, 2.25 p. m. Wind, east, moderate. Tide, full at 1.30, falling. In 400 square feet of shore one cubic yard vegetable matter mainly driftwood and seaweed. Guard says beach was bad last Saturday and Sunday after east wind.

Shore South of Midland Beach to the Great Kills. July 13, 1906, 4.15 p. m. Wind, east. Tide, half full, falling. About the same but large amount of driftwood, as beaches not cleaned.

Summary. Shore of Staten Island polluted with garbage blown ashore by the southeast wind yesterday.

SOUTH BEACH AND MIDLAND BEACH

Fort Wadsworth to Millers Beach. July 25, 1906, 10.15 a. m. Wind, east, light. Tide, full. Very little garbage along shore. Some seaweed and driftwood. Slight evidence of garbage in the shape of decayed vegetables and particles of bread and fat meat.

Millers Bathing Beach. July 25, 1906, 11.20 a. m. Wind, east, light. Tide, high, falling. Shore clean. No garbage now and none seen recently as winds unfavorable.

South to Midland Beach. July 25, 1906, 1.15 p. m. Wind, east, light. Tide, half low, falling. Not much garbage. Some seaweed and driftwood.

Ocean View Beach. Midland Beach. July 25, 1906, 3.20 p. m. Wind, east, light. Tide, low, falling. Shore kept very clean. Reports indicate no trouble lately.

Midland Beach South of Ocean View Bathing Beach. July 25, 1906, 3.50 p. m. Wind, east, light. Tide, low, falling. Not much garbage on shore.

Summary. No evidence of garbage pollution of late, as no long continued southeast winds of sufficient force to bring it to this shore.

FORT WADSWORTH TO MIDLAND BEACH

South Beach, Staten Island Shore Next to Fort Wadsworth. August 20, 1906, 10.20 a. m. Wind, southeast, light. Tide, one-half low, falling. Along 200 feet of shore at high water mark decayed fruit and vegetables. This probably came ashore within past day or so.

South Beach Bathing Beaches. August 20, 1906, 11.30 a. m. Wind, southeast. Tide, low, falling. Cleaned this morning at 10. Observer reports that some garbage comes ashore after several days of southeast winds.

Midland Beach North of Bathing Beaches to Small Inlet. August 20, 1906, 2.20 p. m. Wind, southeast. Tide, low, falling. Estimated about one-tenth cubic foot garbage in 400 square feet.

Midland Beach Bathing Beaches. August 20, 1906, 4.10 p. m. Wind, southeast. Tide, low, rising. Cleaned this morning. A few pieces of garbage on beaches.

Summary. Garbage comes ashore here after two or three days of southeast wind.

THE SHORES OF NEW JERSEY

ATLANTIC HIGHLANDS TO OCEAN GROVE

Atlantic Highlands. July 10, 1906, 10.30 a. m. Wind, west, light. Tide, high, rising. Shore clean except for seaweed and occasional driftwood.

Normandie, near Life Saving Station. July 10, 1906, 10.50 a. m. Wind, west, light. Tide, high, rising. In 400 square feet of shore, $1\frac{1}{2}$ cubic yards vegetable matter, 95 per cent. or more seaweed or driftwood, remainder decayed vegetables and refuse. No odor noticeable. No garbage or sewage seen in water.

Seabright. Shore just north of Seabright Beach Club House. (Beach back of Club House cleaned every morning.) July 10, 1906, 11.10 a. m. Wind, west, light. Tide, high, falling. In 400 square feet of shore, 1 cubic yard vegetable matter, 95 per cent. seaweed and driftwood. Rest, decayed vegetables and refuse. No odor except from dead fish and pig skin nearby. No garbage or sewage seen in water.

Long Branch, West End Bathing Beach. July 10, 1906, 1.10 p. m. Wind, west, light. Tide, high, falling. In 400 square feet of shore, one-half cubic yard vegetable matter, mainly seaweed, some driftwood. No garbage or sewage noted in water.

Asbury Park, Fourth Avenue Bathing Beach. July 10, 1906, 3.15 p. m. Wind, west, light. Tide, half high, falling. Shore very clean except for seaweed mixed with sand. Slight scum of sewage on water noted at one point from sewers which empty 400 or 500 feet out from shore all along the beach. No garbage in the water. No odor.

Ocean Grove, Ross's Bathing Beach. July 10, 1906, 4.10 p. m. Wind, west, light. Tide, low, falling. Shore very clean except for seaweed in the sand. Sewers empty about 400 feet out from low water mark. No sewage or garbage noted in water. No odor.

Summary. The beaches from Normandie to Ocean Grove are polluted with decayed vegetables, dead animals and particles of grease, when the wind has blown from the east or northeast for any length of time. An observer at Seabright said that when the scows dump at 10 or 11 a. m. near the Scotland Light, the decayed vegetables come ashore that evening, if there is an east or northeast wind. Said there had

been no trouble lately. An observer at Long Branch (West End) said that during the last half of June the water was filled with decayed vegetables, grease and dead animals. Since July 1 he had not noticed anything very objectionable. An observer at Asbury Park (Fourth avenue) said that decayed vegetables, grease and dead animals came ashore after an east or northeast wind. Was worse during last of June and Thursday, Friday and Saturday of last week. An observer at Ocean Grove said that the water was full of decayed vegetables during the latter half of June after an east wind, also last Saturday. Said the bathers did not mind the sewage in the water, but disliked the large prominent evidences of decay, such as bad vegetables and dead animals. To-day with a west wind blowing the beaches were very clean, not enough garbage or refuse of any sort to be objectionable. The bathing masters at Asbury said that all the beaches there and at Ocean Grove are cleaned every morning at 7. On a day like this when the wind is west, it takes them one-half hour to do the work. When the wind is east or northeast it requires two to three hours to get the beach free from seaweed, driftwood, decayed vegetable matter, dead animals, etc.

SANDY HOOK

Sandy Hook, N. J., Ocean Shore. August 17, 1906, 6.15 p. m. Wind, southeast, light. Tide, high, falling. Some garbage along shore still wet which came ashore to-day. No great quantity.

Summary. Much garbage on this shore, which is never cleaned.

LONG BRANCH TO SEABRIGHT

Long Branch, a Frequented Bathing Beach. July 27, 1906, 3 p. m. Wind, south. Tide, one-half low, falling. No garbage on this shore, which is kept clean and very little on shore to north which is not cleaned daily. Local observer said they had experienced very little trouble from garbage since last June. Some oranges and lemons were found thrown on beach evidently by bathers or from passing boats; not much decayed and no other vegetables. Some driftwood and seaweed.

Seabright Club House Beach. July 27, 1906, 4.20 p. m. Wind, south. Tide, low, falling. No garbage on this shore, which is kept clean. On shore to the north found some garbage but hardly worth mentioning. This shore cleaned twice a week, not to-day. Some driftwood and seaweed. A life guard will keep daily report. He said garbage came ashore after any strong east wind and that the northeast winds yesterday and day before carried great quantities of garbage from dumping grounds down past his beach. He saw it going by and much of it was caught in the fish nets set off the Club House, about 700 feet from shore. Very little came ashore.

Summary. Long Branch and Seabright shores not polluted by garbage. Northeast winds, of late, took garbage further down the coast, according to reports. Seabright observer reports trouble every time fresh east wind blows. Local observer says he has not seen much garbage since June.

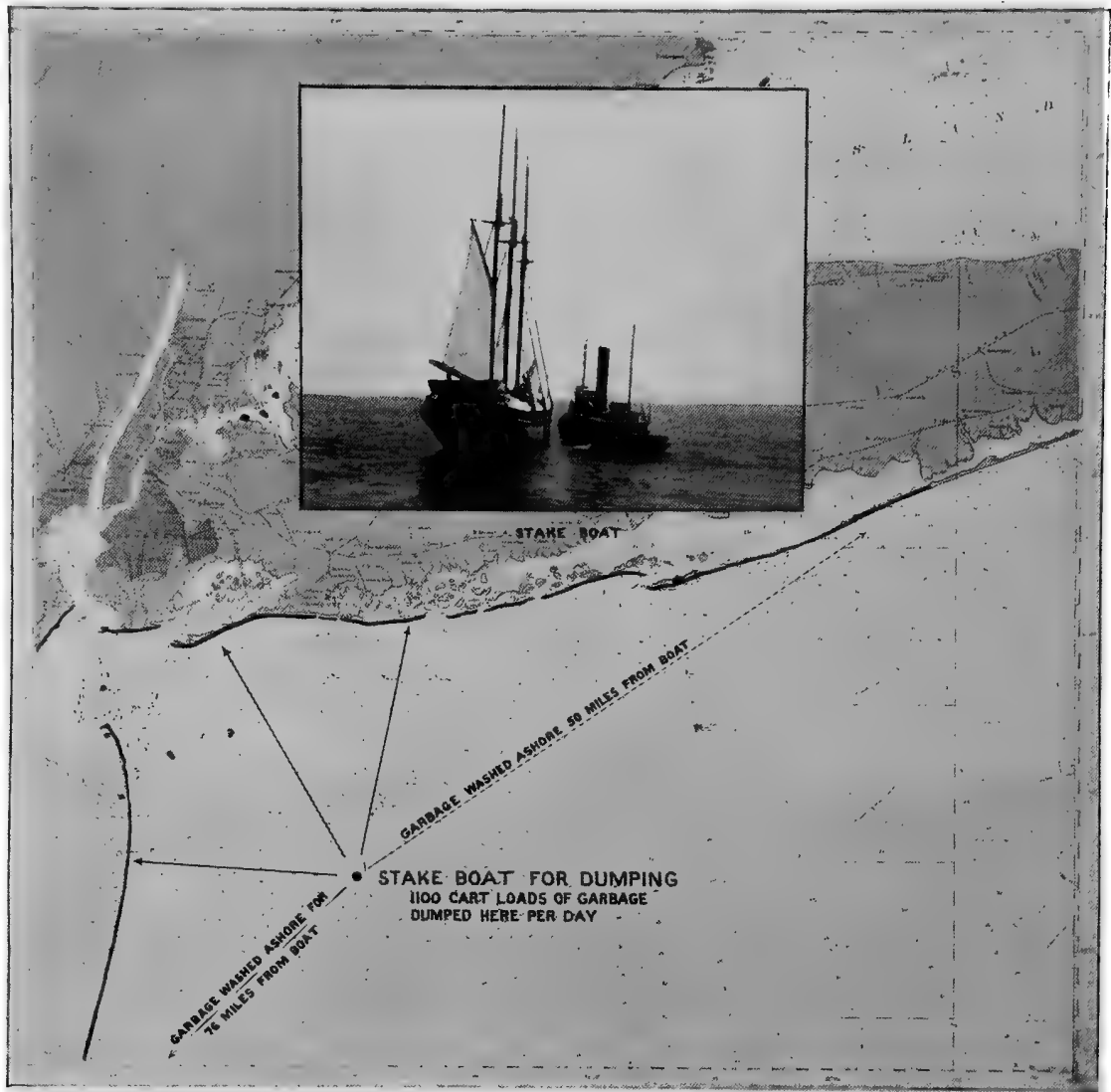
SEABRIGHT TO POINT PLEASANT

Seabright, N. J. August 13, 1906, 11.00 a. m. Wind, northeast, fresh. Tide high, rising. On a line 10 feet wide, about 30 feet back from water, and 40 feet long *i. e.*, in 400 square feet, was about one cubic foot garbage which came ashore last Thursday and Friday, August 9 and 10. Decayed fruits and vegetables. Good many pieces of fat meat and grease. Great quantity of burned or over-roasted coffee. Some garbage is coming ashore this morning. Not much collected so far. A bathing master burned a large quantity of garbage and one dead dog on Friday.

Asbury Park, N. J., Fourth Avenue Baths. August 13, 1906, 2.20 p. m. Wind, northeast, fresh. Tide, high, falling, full at 1.30 p. m. Some garbage coming ashore now. Various sorts of decayed fruit and vegetables, pieces of fat meat and grease, corks and tin boxes. No great quantity. Noticed that considerable was washed up on steep beach and then carried out again with receding tide. S. here reports great quantities garbage, also dead cats, dogs, fowls, etc., as coming ashore August 9 and 10.

Bradley Beach, N. J., from Ocean Grove line to bathing pavilion. August 13, 1906, 4.25 p. m. Wind, northeast, fresh. Tide, one-half low, falling. Along this one-fourth mile of shore an immense quantity of garbage has come ashore since the beach was cleaned this morning, and is still coming in. Most of it is at to-day's high water mark. Observer said he thought more garbage came ashore last Friday, August 10, than at any time since June. Observer said that on Friday a great many people put on their clothes and left the water in disgust after a few minutes, as it was so full of vegetables and grease. One woman decided to leave after a dead dog had come in contact with her face. He said it was twice as bad as to-day. If so, it must have been very filthy. The only way to account for the much greater amount here than along the Asbury and Ocean Grove beaches seems to be on the theory that currents exist here along the shore. The more gradual slope of the beach also prevents the refuse from being washed off again. It is carried far ashore.

Summary. Great quantity of garbage has come ashore to-day on Bradley Beach. A less quantity on Asbury Park, Ocean Grove. Seabright was visited earlier before full tide. Large quantities of garbage came ashore on all these beaches August 9 and 10.



Pollution of Beaches by Garbage.

Noted by the Metropolitan Sewerage Commission
SUMMER OF 1906

SEABRIGHT TO BELMAR

Seabright, N. J. August 6, 1906, 10.50 a. m. Wind, south, light. Tide, high, falling. Good deal of garbage on shore. On a line 20 feet wide, about 50 feet back from water, decayed fruit and vegetables. Estimated quantity of garbage: 1 cubic foot in 400 square feet. This came up Thursday and Friday, August 2 and 3, with wind northeast. Good deal of driftwood and seaweed. Good many dead fish came up this morning but very little else.

West End Bathing Beach, Long Branch, Uncleaned Beach to the North. August 6, 1906, 1.20 p. m. Wind, south, light. Tide, one-half high, falling. About one-half cubic foot garbage in 400 square feet. Less than at Seabright but noticeable. About the same variety of fruit and vegetables, considerable grease. Observer says the only thing that gave trouble on Thursday and Friday was the grease which came ashore.

Asbury Park. August 6, 1906, 3.10 p. m. Wind, south, light. Tide, low, falling. Observer reports great deal of garbage coming ashore August 2 and 3 with northeast wind. The beach has been thoroughly cleaned since then.

Beach Between Ocean Grove and Belmar. August 6, 1906, 4.40 p. m. Wind, south, light. Tide, low. About one-half cubic foot garbage on shore in 400 square feet. All the fruit and vegetables enumerated above. Good deal of grease on the shore. This shore not cleaned since August 2.

Summary. Jersey beaches from Seabright to Belmar show by their present condition that a good deal of garbage came ashore Thursday and Friday, August 2 and 3, with northeast wind. Decayed fruit and vegetables, fat meat, grease, etc., evidently from the New York dumping scows.

POINT PLEASANT TO ASBURY PARK

Point Pleasant, N. J. Casino Beach. July 28, 1906, 10.20 a. m. Wind, south, light. Tide, high, rising. Bathing beach kept clean, but to the north, where beach not cleaned, was large quantity of garbage. Also bottles, driftwood, seaweed, corks and tin cans. Guard said large quantity of garbage came ashore Wednesday and Thursday, July 25 and 26, with fresh northeast winds and that they frequently were troubled with it after strong northeast winds.

Asbury Park. Fourth Avenue. July 28, 1906, 12.15 p. m. Wind, south, light. Tide, full, nearly rising. Beach kept clean, very little garbage now. Life guard here said large quantity of garbage came ashore Wednesday and Thursday, July 25 and 26, with northeast wind and that it took him one and one-half hours to bury the decayed vegetables, fat meat and three dead cats on Thursday.

Ocean Grove. Bathing Beach. July 28, 1906, 2.05 p. m. Wind, south, light. Tide, high, falling. Beach kept clean. No garbage to be seen. Observer says good deal came ashore Thursday and some Wednesday, July 26 and 25.

Shore to the North of Belmar. July 28, 1906, 4.20 p. m. Wind, south, light. Tide, low, falling. Shore not cleaned here often. A good deal of garbage present which probably came ashore Wednesday and Thursday, July 25 and 26, with northeast wind. In 400 square feet about one and one-half cubic feet garbage, decayed vegetables and pieces of fat meat. Also seaweed and driftwood. Slight odor nearby from decayed meat, very little from decayed vegetables, which had not been on shore long after being washed with the salt water.

Summary. The Jersey coast between Asbury Park and Point Pleasant (inclusive) received a good deal of garbage from the ocean on July 25 and 26, when the wind was northeast. This is favorable for driving it there from the dumping grounds.

ASBURY PARK TO POINT PLEASANT

Asbury Park. August 7, 1906, 8.30 a. m. Wind, southeast, light. Tide, high, rising. Very little garbage this morning.

Bradley Beach, opposite Station New Jersey Central Railroad. August 7th, 1906, 9.40 a. m. Wind, southeast, light. Tide, high, rising. Garbage which came ashore August 2 and 3 pretty well cleaned off. None came up during night.

Spring Lake. August 7, 1906, 11.40 a. m. Wind, southeast, light. Tide, high, falling. Shore kept clean. Some pieces of grease in the sand which the rakes of the cleaners missed.

Sea Girt, opposite State Camp. August 7, 1906, 1.25 p. m. Wind, southeast. Tide, high, falling. About $\frac{1}{4}$ cubic foot garbage in 400 square feet, estimating on a line about 50 feet back from water. Probably came up August 2 and 3. Variety of decayed fruit and vegetables, pieces of grease and fat meat. Tin boxes, tooth powder, corks, bottles, bicycle tire, seaweed and driftwood.

Point Pleasant, N. J. August 7, 1906, 3.35 p. m. Wind, southeast, light. Tide, one-half low, falling. Along 1,000 feet of shore to the north on line 50 feet back from the water, small quantity decayed fruit and vegetables. Not enough garbage to estimate.

Point Pleasant, about one-half mile south of above. August 7, 1906, 4.20 p. m. Wind, southeast, light. Tide, low, falling. Shore clean now. Observer said garbage in considerable quantity came ashore August 2 and 3, and that a good deal came in on the ebb tide and was washed out at the next high tide. Good deal was raked up.

Summary. Some garbage on Jersey shore between Asbury Park and Point Pleasant thrown up August 2 and 3 by northeast wind. Garbage includes great variety of decayed fruit and vegetables, grease and fat meat, corks, tin cans, etc.

ASBURY PARK TO SEA SIDE PARK

Asbury Park. August 14th, 6.30 a. m. Wind, southwest, light. Tide, low, rising. Very little garbage came ashore here during night or since last observation at 2.20 p. m. yesterday, because of decrease in wind movement in afternoon and change in direction of wind to southwest in evening.

Bradley Beach. August 14, 1906, 7.15 a. m. Wind, southwest, light. Tide, low, rising. Very little addition to amount of garbage noted in last observation of this shore at 4.25 p. m. yesterday, owing to decreased velocity of wind and later change in its direction.

Point Pleasant. August 14, 1906, 10.30 a. m. Wind, southwest, light. Tide, one-half high, rising. About one-fourth cubic foot of garbage in 400 square feet of shore, which came ashore last Friday, August 10th, according to report of local observer. Beach reported rather filthy on Friday, but not so bad as in June.

Sea Side Park, N. J. August 14, 1906, 3.00 p. m. Wind, southwest, light. Tide, high, falling. Quantity of garbage on this shore estimated at a little less than $\frac{1}{8}$ cubic foot in 400 square feet.

Summary. Bradley Beach seems to have received more garbage of late than any spot on the New Jersey beaches. This was on account of the wind direction or the currents along shore or the gradual slope of the beach, or because of all three.

A considerable quantity of garbage is reported to have come ashore at Seabright and Asbury Park on August 10. Not much with northeast winds August 13.

At Point Pleasant and Sea Side Park hardly enough garbage of late to cause any complaint.

ATLANTIC CITY

Shore from Inlet to Heinze's Pier. August 10, 1906, 8.00 a. m. Wind, east north-east, fresh. Tide, low, rising. Along this one-third mile of shore at the north end of Atlantic City a careful search was made for garbage, as this part is not cleaned, as are the bathing beaches. The two life-savers (United States) seen here said they had seen no garbage on the shore this season. (They were not on duty in June and July.)

Heinze's Pier, South Along the Shore. August 10, 1906, 9.30 a. m. to 12.30 p. m. Wind, east northeast. Tide, high, falling. Eight men were interviewed who were cleaning up the bathing beaches. All agreed that they had seen considerable garbage come ashore here in the latter part of June, but none since. Only one had seen any since July 1, and he referred to ears of corn, which were evidently thrown over from a pier here, as they looked fresh.

Summary. Garbage evidently came ashore at Atlantic City during June. On a certain line were found corks, bottles and tin boxes similar to those accompanying garbage found on other shores. The three pieces of decayed fruit found were on the same line, well dried, and may have come from local sources or from passing steamers, also the one piece of grease.

SURFACE OF ATLANTIC OCEAN BETWEEN LONG BEACH AND BRADLEY BEACH, N. J.,
AUGUST 17 AND 18, 1906.

The wind was southeast, and of scarcely perceptible velocity.

According to the Superintendent of Final Disposition of the Department of Street Cleaning of The City of New York, no garbage had been dumped at sea since August 15th.

From the Fairway buoy at the entrance to Gedney channel the course followed was southeast by one-half south for fifteen miles, measured by a tafrail log. At this point the schooner was found which marks the point for dumping garbage which is carried to sea by tugs from The City of New York.

Large Garbage Fields. Between the Gedney channel and the schooner there were encountered two large fields of floating garbage probably aggregating, so far as could be seen, several hundred acres in extent. The garbage in this field was so thick that there was no square yard of water without some particle of garbage visible from the deck.

At 12 M. the schooner was about to be towed to a new location which lay north by one-half east about seven and one-third miles. From the schooner the tug proceeded westerly to within about a mile or so of the beach at Long Branch, New Jersey. On the way a garbage field like the one already described but smaller in extent was passed.

The tug turned southward at Long Branch, and followed the New Jersey coast as far as Bradley Beach.

Float Observations. Opposite Bradley Beach, the wind being south and toward the shore, observations were undertaken with floats. Two floats were cast overboard, one with an anchor and the other without. Each float consisted of two two-inch planks six feet long, bolted together in the form of a cross. A small flag raised on a flagpole five feet long indicated the location of the float. The wind was south-south-east, and blowing about five or six knots per hour. The tide was rising.

The free float was followed for 1 hour and 13 minutes. It was then taken on board, and the distance logged to the float which was anchored. The distance was three-fourths of a nautical mile. The rate traveled was 0.62 nautical mile per hour, or one mile in 1 hour and 37 minutes. The direction taken by the float was almost directly down the wind toward the New Jersey shore. The distance from the shore was about three miles.

Fields of Garbage off Long Branch. From a point opposite Bradley Beach the tug took a northerly direction, following the beach at a distance of between two and three miles, to Sandy Hook. An extensive field of garbage was encountered near Long Branch. It extended from North Long Branch to Sandy Hook. Sometimes this floating garbage was so thick that every square foot of water contained at least some particle; sometimes only one piece could be seen in 400 square feet.

An inspection of the shore of Sandy Hook, which was visited later, showed that large quantities of garbage had come ashore on this and previous days.

The Hook was rounded by the tug and the night was spent at the government wharf at Sandy Hook.

On August 18th at 7 A. M. the tug proceeded to sea by way of Gedney channel and the Sandy Hook lightship. The weather was calm, no movement of air being perceptible. The course was southeast by east. After logging 17 miles from Sandy Hook lightship the schooner which marked the new location of the dumping ground was reached.

Garbage-fields 17 Miles at Sea. Between Sandy Hook lightship and the new location of the schooner the tug passed through two extensive fields of garbage. One of these was near the lightship; the second was about three miles west of the schooner. No garbage had been dumped at the schooner since she had been towed to her present location, the day before in the early afternoon.

From the schooner the tug proceeded north by west toward Long Beach, L. I. A field of several acres of garbage was found about three miles from the shore. When within about two miles of the Long Island beach the tug turned westerly and followed the shore line to a point opposite Rockaway Point. An extensive field of garbage was passed opposite Arverne.

Velocity of Travel of Garbage Field. At a point about two miles southwest of Rockaway bell buoy observations were made with floats. As in the experiment of the previous day one float was anchored and the other was allowed to drift. The wind was south by west about seven miles per hour. The tide was rising. The free float was taken on board 1 hour and 15 minutes after it had been set adrift. By logging the distance from the point where it was picked up to the point where it was launched, beside the anchored buoy, it was found that it had drifted fifteen-sixteenths of a mile. This was at the rate of one mile in 1 hour and 25 minutes, or about 0.62 miles per hour. A small field of garbage at the edge of which the float had been launched traveled as rapidly as did the float itself.

From opposite Rockaway bell buoy the tug proceeded toward Coney Island, following the Coney Island channel to the Narrows, and thence to the Battery.

Garbage Fields in Lower Bay. Garbage fields were passed on the way opposite Coney Island, Gravesend bay, the Narrows and the lower end of the Upper bay.

Summary. In summarizing the observations made on this trip it is to be noted that garbage was found floating on the water along the shores of Long Island and New Jersey, and on two lines nearly midway between these shores, about as far as the point where the garbage is believed to be dumped. In fact garbage was found floating on the water at every and all points visited. In some cases the fields were many acres in extent, and so thickly strewn with refuse that no square foot of water could be found without some particle of garbage in it. Floating barrels, tin cans, bottles and other solid articles commonly mixed with city garbage were frequently seen where no particles of garbage could be found. In two cases the surface currents were driving refuse toward the beaches at a rate of one-half a nautical mile per hour.

The amount of garbage found, its location, distribution, and to some extent, its composition, made it appear practically certain that the garbage found was garbage

from New York which had been dumped some days previously at sea. Although it had been announced that a scow load of garbage would be carried to sea on August 18th, no trace of it or of the boats which were to convey it could be discovered.

SECTION III

INSPECTIONS BY THE LIFE-SAVING SERVICE OF THE NEW JERSEY AND LONG ISLAND COASTS

Following is the substance of reports received from keepers of life-saving stations on the New Jersey and Long Island coasts concerning the condition of the beaches with respect to garbage washed up from the sea, during the summer of 1906, furnished by the United States Life-Saving Service, Washington, D. C.

COAST OF NEW JERSEY

Sandy Hook. Aug. 12-18th, no garbage.

Spermaceti Cove. Aug. 9th, found about ten dead cats, some pineapples, bread and lemons; Aug. 10th and 11th, same, nothing new noticed; Aug. 13th, small quantity fruit; Aug. 15th, three dead cats and some lemons; Aug. 16th, dead chicken and chicken entrails; week 19th to 25th, garbage washed ashore very light; Friday, 24th, two cats and some fruit.

Seabright. Aug. 9th, small quantities, principally burnt coffee and wood; Aug. 10th, large quantity of driftwood; Aug. 11 to 17th, no garbage; Aug. 18th, large quantity of table refuse and dead animals; Aug. 19th to 23rd, no garbage; Aug. 24th and 25th, small quantities of garbage.

Monmouth Beach. Aug. 9th, large quantity of garbage and driftwood; Aug. 10th and 11th, very little garbage; Aug. 12th, no garbage; Aug. 13th and 14th, very little; Aug. 15th, large quantity of driftwood; Aug. 16th and 17th, very little garbage; Aug. 18th, small quantity; Aug. 19th to 24th, very little; Aug. 25th, small quantity of garbage but much driftwood; 27th and 28th, very little garbage; 29th, small lot of garbage, large quantity driftwood; 30th, little garbage; 31st, no garbage.

Long Branch. Aug. 9th, no garbage; 10th, small lots; 11th and 12th, none; 13th, small lots; 14th, none; 15th, small lots; 16th to 23rd, no garbage; 24th, small quantity; 25th, none.

Deal. Aug. 9th to 12th, large quantities of garbage, consisting of meats, grease, fruits of all kinds; 13th to 16th, wind off shore, so no garbage coming in; beach cleared of old deposits by the 16th; 17th, wind shifted to light south and southwest; nothing coming in up to 25th; wind shifted to north and northeast.

Shark River. Aug. 5th and 6th, beach strewn with decayed fruit and vegetables; 7th, beach mostly clear, washed off on high water; 8th, light lots of garbage coming in; 9th to 11th, beach strewn with fruit, vegetables and grease; 12th, no more coming in; 13th, none coming in; deposits rapidly being covered with sand by heavy surf; 14th to 25th, none coming, beach clean.

Spring Lake. Aug. 9th to 11th, large quantities coming in; 12th to 13th, considerable garbage on beach; 14th to 16th, very little; 17th, beach practically clear; 18th, small lots; 19th and 20th, very little; 21st to 23rd, no garbage coming in; 24th and 25th, considerable drift on beach.

Squan Beach. Beach in deplorable condition since July 25th, very offensive odor, quantities of greasy tallow. People living along shore had to rake and bury it; shoes covered with grease after walking beach; patrolmen obliged to clean shoes thoroughly after each trip before entering station; deposits consist of decayed vegetable matter, green corn, onions, pumpkins, apples, bananas and pineapples; also barrels, boxes and lumber; dead cats, dogs, chickens, decayed meat and "lights" of dead animals. It comes in with northeast and east winds and current running from north. Aug. 9th and 10th, beach in bad condition; 12th to 15th, same; 15th, wind southwest to east; quantities of grease and decayed vegetables; 17th to 23rd, no drift; 24th, wind northeast to east-northeast, strong; sticks, logs, barrels, boxes and vegetables coming in; 25th, no drift.

Bayhead. Week Aug. 5th to 11th, slight drift, consisting of leaves and tops of vegetables; week Aug. 12th to 18th, some fish and dog carcasses; week 19th to 25th, no garbage.

Mantoloking. Aug. 6th, very little garbage; 7th, little; 8th to 11th, considerable driftwood and garbage; some grease; 12th to 18th, very little garbage and driftwood; 20th, some driftwood; 21st and 22nd, none; 23rd to 25th, some driftwood.

Chadwick. Aug. 9th, small lots of garbage, fruit and meat; 10th, considerable driftwood; 11th, some wood and fruit; 12th, wood; 13th, wood and apples; 14th to 18th, no garbage.

Toms River. Aug. 8th to 21st, no garbage; 22nd, barrels and driftwood, small lots; 23rd to 25th, same.

Island Beach. Keeper reports large quantities of garbage on beach, but intimates that most of it was dumped there by local residents; some decayed vegetable and animal matter washed up by sea; also fish thrown along beach by local fishermen; local dumping of garbage has been stopped.

Cedar Creek. Aug. 10th to 25th, clean beach, no garbage.

Forked River. Aug. 5th to 18th, no garbage.

Barnegat. Aug. 9th to 25th, no garbage.

Loveladies Island. Beach in good condition from Aug. 1st to 9th; 10th and 11th, light drift of garbage; 12th to 18th, none.

Harvey Cedars. Aug. 8th to 25th, beach clear of garbage.

Ship Bottom. Aug. 12th to 14th, light drift of vegetables, apples, onions and cabbages; 15th to 25th, none.

Long Beach. Aug. 9th, no garbage; 10th, few pineapples; 11th to 18th, none.

Bonds. Aug. 9th to 25th, no garbage.

Little Egg. Aug. 1st to 11th, no garbage.

Little Beach. Aug. 11th to 25th, no garbage.

Brigantine. Aug. 11th to 25th, no garbage.

Atlantic City. No garbage; city scavengers look after beach.

Absecon. Aug. 6th to 19th, no garbage noticed.

Great Egg. Aug. 12th to 18th, beach perfectly clean.

Ocean City. Aug. 5th to 16th, no garbage; 17th and 18th, small quantities; 19th, none; 20th, small quantity; 21st to 25th, none.

Pecks Beach. Aug. 9th, small quantities; 10th, considerable driftwood; 11th, large quantities grass, with few decaying vegetables; 12th and 13th, more grass with occasional vegetables; 14th, none; 15th, little decaying matter; 16th, none; 17th, some little drift; 18th, wood, bottles and general refuse; 19th, considerable garbage; 20th, little garbage coming in; 23rd, none; 24th and 25th, small lot of refuse landing.

Corsons Inlet. Aug. 10th to 17th, clean beach; 18th, light miscellaneous drift, evidently from garbage heap; 19th, same; 20th to 25th, clean beach, except for eel grass.

Sea Isle City. No garbage on beach Aug. 5th to 25th.

Avalon. No garbage, Aug. 5th to 18th.

Tathams. Aug. 8th to 11th, no garbage; 12th to 18th, no report; 19th to 25th, no garbage.

Two Mile Beach. Aug. 12th to 18th, no garbage.

Cold Spring. No garbage from Aug. 9th to 25th.

Cape May. Beach patrolled by this station clean.

COAST OF LONG ISLAND

Rockaway Point. Aug. 1st to 25th, no garbage; 26th to Sept. 1, some ashes.

Rockaway. Aug. 1st to 18th, no garbage; 19th, few decayed lemons; 20th, little garbage, old; 21st, considerable, in decomposed condition; 22nd to Sept. 2nd, no garbage.

Long Beach. Aug. 1st to Sept. 2nd, no garbage and little driftwood.

Point Lookout. Aug. 6th to Sept. 2nd, no garbage.

Short Beach. Aug. 12th to Sept. 1st, no garbage.

Zachs Inlet. Aug. 1st to Sept. 3rd, no garbage.

Jones Beach. Aug. 1st, decayed vegetables and driftwood; 2nd and 3rd, same; 4th to 28th, no garbage; Aug. 29th to Sept. 1st, decayed fruit and vegetables.

Gilgo. Aug. 1st, fresh garbage coming ashore; 2nd to 21st, no garbage; Aug. 22nd, old garbage coming in; 23rd to Sept. 3rd, no garbage.

Oak Island. Aug. 1st, some old garbage coming in; 2nd to Sept. 1st, no garbage.

Fire Island. Aug. 5th to 19th, no garbage coming in; 20th, 21st, some old garbage coming in; 22nd to 25th, no garbage.

Point of Woods. Aug. 1st to 4th, no garbage; 5th, some old boards; 6th to 19th, no garbage; 20th, some garbage coming in fresh; 21st, old garbage coming in; 22nd, fresh garbage coming in; 23rd to 25th, no garbage; 26th to 30th, no garbage.

Lone Hill. Aug. 1st to 20th, no garbage; 21st to 23rd, small lots of old garbage coming in; 24th to Sept. 1st, no garbage.

Blue Point. Aug. 1st to 20th, beach clear, no garbage; 21st, considerable refuse, consisting of decayed fruits and vegetables, washed up by fresh southwest wind, remaining 22nd and 23rd; 24th to Sept. 2nd, beach clear of garbage.

Bellport. No garbage; 27th to 30th, slight deposit; 31st and Sept. 1st, beach clean.

Smiths Point. Aug. 1st to 19th, beach clear; 20th, 21st and 24th, small lots of decayed vegetables and fruit; 22nd, 23rd and 25th to Sept. 2nd, no garbage.

Forge River. Aug. 1st to 21st, no garbage on beach; 22nd, small quantity old garbage washed in; 23rd, 24th, none; 25th, very small quantity old garbage; 26th to Sept. 1, none.

Moriches. Aug. 1st to 21st, no garbage on beach; 22nd, some decayed fruit, long time in water; 23rd to Sept. 3rd, no garbage.

Potunk. Aug. 1st to 21st, no garbage; 22nd, a very little garbage, long time in water; 23rd to Sept. 3rd, no garbage.

Quogue. Aug. 1st to 22nd, no garbage; 23rd, decayed vegetables, one cat, and some bottles; 24th to Sept. 2nd, no garbage.

SECTION IV

QUANTITIES OF NEW YORK GARBAGE DUMPED AT SEA DURING JULY
AND AUGUST, 1906

The number of loads of garbage dumped at sea, according to records supplied by the New York Street Cleaning Department, and the force and direction of the wind at New York, according to the records of the United States Weather Bureau, are given in Table I. Until August 17th the garbage was dumped at a stake boat located fifteen nautical miles southeast by one-half south of the Fairway buoy at the entrance of Gedney channel. On August 17th this stake boat was moved to a new location, north by one-half east, about seven and one-third miles from the original position of the stake boat. This placed the stake boat about seventeen miles southeast by east of the Sandy Hook lightship, as logged by the tug Nichols on August 18. It was twenty-two miles to the Jersey shore and fifteen to Long Island.

TABLE I
NEW YORK GARBAGE DUMPED AT SEA.

Date		Garbage in Cart Loads	Wind—Miles Per 24 Hours	
			Direction	Miles
July	6, 1906.....	1,228	Northeast	352
"	7.....	857	Northeast	349
"	8.....	.....	North	176
"	9.....	1,852½	West	174
"	10.....	983½	Northwest	193
"	11.....	2,069½	Northeast	170
"	12.....	1,265½	Southeast	130
"	13.....	746½	Southeast	142
"	14.....	1,500	Northeast	215
"	15.....	596½	West	137
"	16.....	1,134	South	174
"	17.....	1,640	West	221
"	18.....	1,810½	West	170
"	19.....	1,391½	Northeast	176
"	20.....	836	Southeast	157
"	21.....	1,300½	Northwest	148
"	22.....	1,233½	South	142
"	23.....	1,471½	South	262

DATA COLLECTED

TABLE I—*Continued*

Date		Garbage in Cart Loads	Wind—Miles Per 24 Hours	
			Direction	Miles
July	24.....	.....	North	244
"	25.....	1,535½	North	248
"	26.....	2,264	Northeast	268
"	27.....	.....	Southeast	144
"	28.....	2,592	South	214
"	29.....	363½	South	258
"	30.....	1,008½	West	296
"	31.....	964	West	128
August	1.....	1,457½	Northeast	231
"	2.....	279½	Northeast	351
"	3.....	1,146½	East	221
"	4.....	1,435½	West	163
"	5.....	760½	Southwest	138
"	6.....	361½	West	209
"	7.....	1,577	Northeast	143
"	8.....	476	Northeast	170
"	9.....	1,025½	Northeast	225
"	10.....	1,272	East	171
"	11.....	.....	West	174
"	12.....	1,391½	North	197
"	13.....	533½	Northeast	260
"	14.....	485½	Northwest	252
"	15.....	1,502	North	205
"	16.....	.....	South	131
"	17.....	571½	Southeast	136
"	18.....	966	South	136
"	19.....	958½	South	172
"	20.....	551½	South	234
"	21.....	.....	South	180
"	22.....	637½	South	163
"	23.....	1,956½	West	193
"	24.....	.....	Northeast	396
"	25.....	.....	East	338
"	26.....	1,302½	Southeast	239
"	27.....	804½	Northwest	276

CHAPTER VII

BACTERIAL CONTENT OF THE HARBOR WATERS

COLLECTION AND EXAMINATION OF SAMPLES

Previous investigations had shown that the numbers of bacteria in the harbor water might serve as a useful index of the concentration of sewage pollution. The analyses recorded in this chapter were made with this fact in mind and show how the quality of the water varied in different places.

Collection of Samples. The samples of water for the bacterial determinations were collected in glass vacuum tubes. These were lowered to the required depth in a weighted sampling apparatus and the samples were plated out at once on the boat which was properly equipped for the purpose.

Plating Samples. The culture medium used was 10 per cent. gelatin, made from fresh meat, with a reaction of +1.0 per cent. Phenolphthalein was used as an indicator. Ten cubic centimeters of gelatin were used in pouring. The culture plates were hardened on the slate shelves of a refrigerator fitted up on the boat for this purpose. On reaching shore the plates were transferred to the incubator and after incubation for 48 hours at 20° C. the colonies were counted.

Locating Samples. The places from which samples of water, or of mud deposits, were obtained were sometimes located by observing the distance from one or more points on shore, or from fixed buoys or lighthouses, and sometimes by means of compass observations of the directions of three or more of these points.

The location was determined in narrow streams, or when near shore in other sections, by estimating the distance from the points on shore and finding the directions from these points by the compass. When at a long distance from shore, after the boat had anchored and had swung about with the tide, angles were read with a sextant to prominent points on shore such as chimneys, towers and buildings or lighthouses. Three angles were read in every case, an effort being made to get angles between 20° and 180°. The locations were plotted from these readings on charts in the Commission's office by the use of a three-arm protractor.

When the samples were collected observations were made of the exact time of collection, of the directions of the tidal currents, the depths of the water, the depths at which the samples were taken, the temperature and specific gravity of the water and the direction and velocity of the wind; any fact of unusual interest was also recorded.

Care was taken to get representative samples in each case; few samples were taken in slips and at points near sewer outfalls. In Gravesend and Jamaica bays,

where a special study was made of the conditions along the shores, the samples taken near the sewer outlets were excluded in computing the averages.

Surface samples were collected one foot below the surface and bottom samples one foot above the bottom of the water.

GENERAL RESULT OF EXAMINATIONS

The average numbers of bacteria in the water during ebb and during flood tides were determined for the period from March 26th to October 5th, 1909, in the various sections of New York harbor from 1,082 analyses. The average numbers at the surface and at the bottom during the same period in the various sections were determined from 863 analyses.

Larger numbers of bacteria were found during ebb than during flood tides except in the case of the East river between Throgs Neck and Hell Gate where less polluted water from Long Island Sound flowed in during ebb tides. Higher numbers of bacteria were found near the surface than at the bottom. The decrease in numbers at the bottom was quite marked, especially at points where the depth was very great, as at the Narrows and in the Atlantic ocean.

Maximum and Minimum Counts. The smallest numbers were in samples taken in the Atlantic ocean off Long Branch. The smallest number of bacteria in any sample was 35 at a depth of 150 feet in the ocean ten miles off Long Branch.

The next smallest numbers were found in the water of Long Island Sound, in which section the average of all samples was 375.

The highest numbers were in samples taken in the Passaic river at Newark, where the average for all samples was 92,000.

The greatest numbers in the harbor proper were in samples taken in the Upper bay, the lower parts of the East and Hudson rivers and in the Harlem river. The average for the Upper bay was 14,500. The average for the Harlem river was 15,000.

The numbers in the Upper bay decreased at the Narrows and were decidedly smaller in the Lower bay; in the ocean comparatively few bacteria were found.

The numbers in the East river were less in the region just below Hell Gate and were small in the East river between Hell Gate and Throgs Neck; in Long Island Sound the numbers were quite small.

The numbers in the Hudson river were much smaller in the part above Spuyten Duyvil than in the portion to the south thereof.

The greatest numbers were in samples taken near the sewer outlets or in badly polluted streams such as the Passaic river.

Gowanus canal, Newtown creek and Wallabout canal did not receive much attention because of their manifestly offensive condition.

The Arthur Kill showed quite low numbers of bacteria after the flow of flood currents from Raritan bay.

Jamaica bay showed large numbers of bacteria along the Brooklyn shore near Second creek and along the Arverne shore.

In the Harlem river near the East river the numbers ran particularly high, one sample giving a count of 120,000. The numbers were lower as the Hudson river was approached.

Upper Bay. In the Upper bay the average number of bacteria during the ebb tide was 16,000. During flood tide there were 10,000 per cubic centimetre. The average number at the surface was 22,000; at the bottom there were 12,000 per cubic centimetres. The average number at all tides and all depths was 14,500 per cubic centimetre.

Hudson River. In the Hudson river from its mouth to Spuyten Duyvil the average number of bacteria during ebb tide was 7,700 and during flood tide 4,800 per cubic centimetre. The average number at the surface was 8,200 and at the bottom 4,600 per cubic centimetre. The average number for all tides and all depths was 6,600 per cubic centimetre.

In the Hudson river from Spuyten Duyvil to the upper end of Yonkers the average number of bacteria during ebb tide was 6,500. During the flood tide there were 6,000 per cubic centimetre. The average number at the surface was 7,500 and at the bottom 6,000 per cubic centimetre. The average number for all tides and all depths was 5,300 per cubic centimetre.

East River. In the East river from the mouth to Hell Gate the average number of bacteria during ebb tide was 10,000. During flood tide there were 5,600 per cubic centimetre. The average number at the surface was 11,500 and at the bottom 6,100 per cubic centimetre. The average number for all tides and all depths was 8,700 per cubic centimetre.

In the East river from Hell Gate to the entrance of Long Island Sound at Throgs Neck the average number of bacteria during ebb tide was 1,800. During flood tide there were 4,700 per cubic centimetre. During ebb tide the currents in this section run from Long Island Sound westward and during the flood tide from Hell Gate toward the Sound.

The average number at the surface was 3,700 and at the bottom 2,700 per cubic centimetre. The average number for all tides and all depths was 3,400 per cubic centimetre.

Long Island Sound. In Long Island Sound the average number of bacteria during ebb tide was 540. During flood tide the number was 255 per cubic centimetre.

The average number at the surface was 950 and at the bottom 370 per cubic centimetre.

The average number for all depths and all tides was 375 per cubic centimetre. These averages were based on a series of samples taken about every six miles from Orient Point to Throgs Neck on a trip of the Commission's boat.

Harlem River. In the Harlem river average number of bacteria during ebb tide was 16,000. During flood tide there were 15,000 per cubic centimetre.

During ebb tide the currents in the Harlem river were from the East river toward the Hudson river and during the flood tide from the Hudson river toward the East river.

The average number at the surface was 23,000 and at the bottom 11,000 per cubic centimetre.

The average number for all tides and all depths was 15,500 per cubic centimetre.

Kill van Kull. In the Kill van Kull the average number of bacteria during ebb tide was 6,700 and during flood tide 5,400 per cubic centimetre.

The average number at the surface was 7,700 and at the bottom 4,900.

The average number for all tides and all depths was 6,600 per cubic centimetre.

Newark Bay. In Newark bay the average number of bacteria during ebb tide was 9,000 and during flood tide 6,000 per cubic centimetre.

The average number at the surface was 9,000 and at the bottom 6,700 per cubic centimetre.

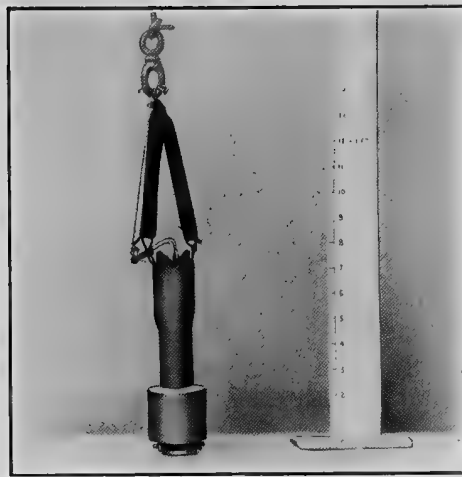
The average number for all tides and all depths was 7,400 per cubic centimetre.

Passaic River. In the Passaic river at Newark the average number of bacteria during ebb tide was 141,000. During flood tide the number was 65,000 per cubic centimetre.

The average number at the surface was 111,000 and at the bottom 75,000 per cubic centimetre.

The average number for all tides and all depths was 92,000 per cubic centimetre.

Arthur Kill. In the Arthur Kill the average number of bacteria during the ebb tide was 7,400, and during the flood tide after the comparatively unpolluted water from Raritan bay had entered the Kill, 350 per cubic centimetre.



Bacterial Water Sampler. The neck of the glass vacuum tube was broken off when the apparatus was lowered to the depths at which a sample was to be taken



The Floating Laboratory. This boat was especially equipped for laboratory work. Water samples were plated and dissolved oxygen analyses were made on this boat

The average number at the surface was 5,400 and at the bottom 4,100 per cubic centimetre.

The average number for all tides and all depths was 4,700 per cubic centimetre.

The Narrows. In the Narrows the average number of bacteria during ebb tide was 6,700 and during flood tide 2,500 per cubic centimetre.

The average number at the surface was 8,300. At the bottom the number was 1,900 per cubic centimetre.

The average number for all tides and all depths was 4,900 per cubic centimetre.

Gravesend Bay. In Gravesend bay the average number of bacteria during flood tide was 4,500 per cubic centimetre. Too few samples were taken during ebb tides to yield a fair average.

The average number at the surface was 4,500 per cubic centimetre. No bottom samples were taken on account of the shallowness of the bay.

The average number for all samples, excluding those samples taken near sewer outlets, was 4,500 per cubic centimetre.

Lower Bay. In the Lower bay the average number of bacteria during ebb tide was 1,400 and during flood tide 1,200 per cubic centimetre.

The average number at the surface was 1,900 and at the bottom 1,100 per cubic centimetre.

The average number for all tides and all depths was 1,300 per cubic centimetre.

Rockaway Inlet. In Rockaway inlet the average number of bacteria during ebb tide was 2,900 and during flood tide 1,200 per cubic centimetre.

The average number at the surface was 2,000. No deep samples were taken.

The average number for all tides and all depths was 2,000 per cubic centimetre.

Jamaica Bay. In Jamaica bay the average number of bacteria during ebb tide was 6,600 and during flood tide the number was 3,400 per cubic centimetre.

The average number at the surface was 8,600 and at the bottom 3,800 per cubic centimetre.

The average number for all tides and all depths was 7,400 per cubic centimetre, excluding those samples taken near sewer outlets.

Atlantic Ocean. In the Atlantic ocean, ten miles off Long Branch, the average number of bacteria during flood tide was 120 per cubic centimetre. No samples were taken during ebb tide.

The average number at the surface was 200 and at the bottom 35 per cubic centimetre.

The average number for all the samples taken was 120 per cubic centimetre.

The average number of bacteria at the surface and at the bottom are shown in Table I.

The average number of bacteria in the ebb and flood tides are shown in Table II.

The relation between average numbers of bacteria and the dissolved oxygen content of the harbor waters is shown in Table III.

TABLE I

AVERAGE NUMBER OF BACTERIA IN THE WATER AT THE SURFACE AND AT THE BOTTOM,
MARCH 26 TO OCTOBER 5, 1909

Location of Samples	Depths			
	Surface		Bottom	
	Number of Analyses	Bacteria per c. c.	Number of Analyses	Bacteria per c. c.
Upper bay.....	43	22,000	30	12,000
Hudson river, below Spuyten Duyvil.....	62	8,200	59	4,600
Hudson river, above Spuyten Duyvil	20	7,500	20	6,000
East river, below Hell Gate.....	48	11,500	48	6,100
East river, Hell Gate to Long Island Sound	13	3,700	13	2,700
Long Island Sound.....	22	950	22	370
Harlem river	28	23,000	18	11,000
Kill van Kull.....	40	7,700	36	4,900
Newark bay.....	19	9,000	19	6,700
Passaic river at Newark.....	4	111,000	4	75,000
Arthur Kill.....	10	5,400	9	4,100
Narrows	15	8,300	12	1,900
Gravesend bay.....	9	4,500	..	.....
Lower bay	105	1,900	90	1,100
Rockaway inlet.....	6	2,000	..	.....
Jamaica bay.....	23	8,600	6	3,800
Atlantic ocean, ten miles off Long Branch	2	200	2	35

Note. In figuring the above averages, all the samples collected one foot under the surface and those collected one foot above the bottom were included, except that in the cases of Gravesend and Jamaica bays those samples collected near sewer outlets were not included. Those samples collected at depths between the surface and bottom were not included.

TABLE II
AVERAGE NUMBER OF BACTERIA IN THE WATER DURING EBB AND FLOOD TIDES, MARCH
26 TO OCTOBER 5, 1909

Location of Samples	Tides			
	Ebb		Flood	
	Number of Analyses	Bacteria per c. c.	Number of Analyses	Bacteria per c. c.
Upper bay	73	16,000	19	10,000
Hudson river, below Spuyten Duyvil	85	7,700	79	4,800
Hudson river, above Spuyten Duyvil	23	6,500	32	6,000
East river, below Hell Gate	67	10,000	65	5,600
East river, Hell Gate to Long Island Sound	15	1,800	18	4,700
Long Island Sound	21	540	25	255
Harlem river	31	16,000	27	15,000
Kill van Kull	63	6,700	38	5,400
Newark bay	21	9,000	24	6,000
Passaic river at Newark	4	141,000	4	65,000
Arthur Kill	12	7,400	7	350
Narrows	27	6,700	22	2,500
Gravesend bay .....	..	....	9	4,500
Lower bay	119	1,400	111	1,200
Rockaway inlet	3	2,900	3	1,200
Jamaica bay	19	6,600	6	3,400
Atlantic ocean, ten miles off Long Branch .....	..	....	4	120

Note. In figuring the above averages, all the samples collected in the various sections were included, except that in the cases of Gravesend and Jamaica bays, those samples collected near sewer outlets were not used.



The Figures in Circles Show the Number of Bacteria per Cubic Centimetre in the Water in the Localities Indicated by Shading

TABLE III

AVERAGE NUMBER OF BACTERIA AND AVERAGE PER CENT. OF SATURATION WITH OXYGEN
IN THE WATER OF THE VARIOUS SECTIONS OF NEW YORK HARBOR FOR ALL DEPTHS
AND TIDES FROM MARCH 26 TO OCTOBER 5, 1909

Averages of 800 Oxygen and 1,082 Bacterial Analyses

Location of Samples	Number of bacteria per c. c.	Per cent. of saturation with oxygen
Upper bay	14,500	67
Hudson river, below Spuyten Duyvil	6,600	72
Hudson river, above Spuyten Duyvil	5,300	83
East river, below Hell Gate	8,700	65
East river, Hell Gate to L. I. Sound	3,400	86
Long Island Sound	375	99
Harlem river	15,500	55
Kill van Kull	6,600	79
Newark bay	7,400	76
Passaic river at Newark	92,000	6
Arthur Kill	4,700	82
Narrows	4,900	83
Gravesend bay	4,500	90
Lower bay	1,300	97
Rockaway inlet	2,000	97
Jamaica bay	5,800	76
Atlantic ocean—ten miles off Long Branch	120	100

Note. In figuring the above averages all the samples collected in the various sections were included, except that in the cases of Gravesend and Jamaica bays those samples collected near sewer outlets were not used.

CHAPTER VIII

EVIDENCE OF POLLUTION OF HARBOR WATERS WITH SPECIAL REFERENCE TO THE EXHAUSTION OF THE DISSOLVED OXYGEN

ANALYTICAL METHODS

The investigations which are described in the following pages were made to ascertain the extent of the pollution of New York harbor and its tributary waters in the metropolitan district as shown by the amount of dissolved oxygen which they contain as compared with the normal amount which should be present in the absence of decomposing organic matter.

Unpolluted waters, both land waters and sea waters, have power to absorb atmospheric oxygen, the quantities absorbed being dependent upon temperature and pressure and a number of other conditions. The laws which govern these phenomena are complex, but much experimental study has been given the subject with the result that the rate of absorption and the quantities of oxygen which can be held in solution have been determined for both land and sea waters as well as for mixtures of these at various temperatures.

When decomposing organic matter is discharged into either land or sea water a certain amount of the dissolved oxygen in the water is used up by processes of nature in converting these matters into gases and mineral salts, leaving the water, while the processes are going on, deficient in dissolved oxygen. The amount of this deficiency is a measure of the activity of the processes of decomposition and of the capacity of the water in question to receive and oxidize additional quantities of decomposable organic matter. When the dissolved oxygen is all consumed by processes of oxidation the further addition of decomposable organic matter will, under most conditions, result in putrefaction and the consequent evolution of foul odors.

Albert Levy Method Used. In considering tests for the determination of the oxygen dissolved in the harbor waters, choice was made of the Albert Levy method. This is the process employed by Professors Letts and Adeney and described in the fifth report of the Royal Commission on Sewage Disposal. Professors Letts and Adeney had made a large number of examinations of the waters of tidal estuaries on the

British coast and had done a large amount of work in determining the capacity of tidal waters for digesting sewage.

Testing of Method. Before putting the test into execution it was thought well for the Commission to request Professor Floyd J. Metzger, Ph. D., of Columbia University, to examine the method and make suggestions which would adapt it to the Commission's use. A large number of determinations were to be made and the time available for each should be as short as was consistent with accuracy. The method as reported by the Royal Commission, required a long time for the precipitated oxides of iron to dissolve in the acid, this process taking apparently about three hours. Accordingly, Professor Metzger made some experiments to shorten this period and in March, 1909, reported that he had been successful in reducing the time to five minutes. The time required from the beginning to the end of an analysis was about 30 minutes.

The Commission then proceeded to have the necessary apparatus made. Throughout the work the standard solutions were prepared by Professor Metzger and delivered to the Commission's laboratory for use.

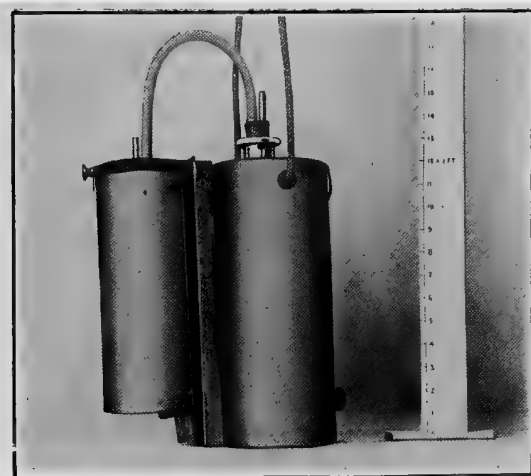
The samples for analysis were collected from one of the Commission's boats which was especially equipped for this purpose. The analyses were made on board immediately after the sample was collected.

Opinion of Professor Gill on Method. In order to be as certain as possible concerning the accuracy of the results, Professor Augustus H. Gill, Ph. D., of the Massachusetts Institute of Technology, was requested to examine the work performed by the Commission and express an opinion concerning the accuracy of the results. Professor Gill reported on November 15, 1909, that he had carefully examined the method for determining dissolved oxygen used by the Metropolitan Sewerage Commission. He said:

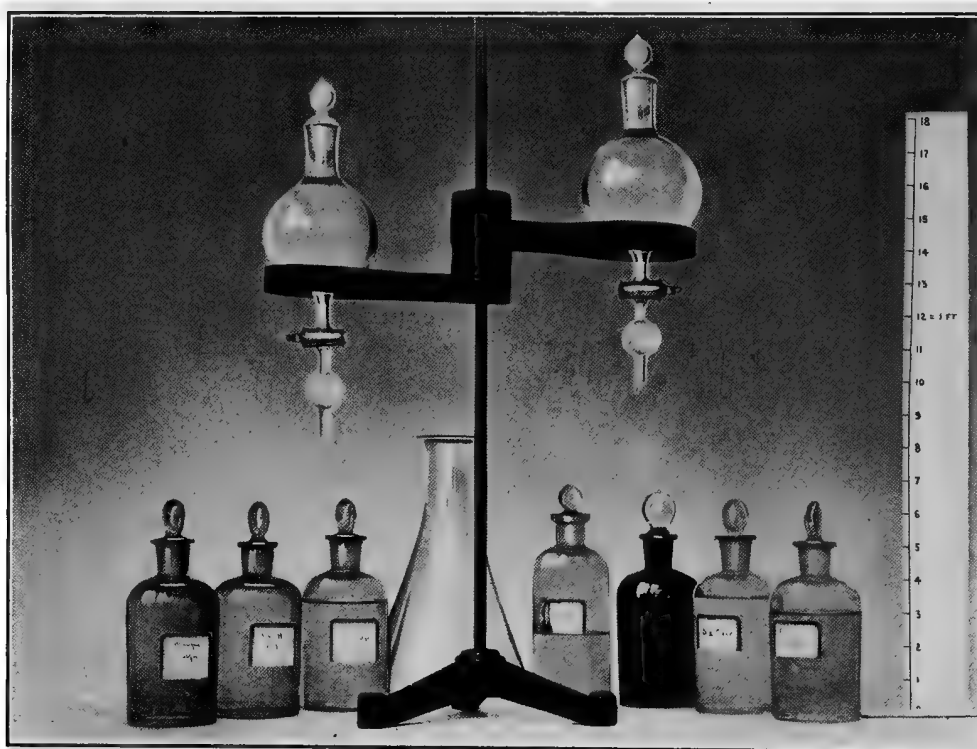
"The method that I saw carried out in your laboratory by Dr. Parsons would seem to leave nothing to be desired in the point of technique, either as regards sampling or treatment of samples thereafter. The results obtained seemed to me to be what might be well expected, considering the extensive pollution of New York Harbor. While the method followed—Albert Levy Method—may on theoretical grounds be open to question and possibly some determinations be now and then affected, I am of the opinion that the work done represents the true condition of the harbor and any determination affected would not be material.

"I have said that the method may be open to question on theoretical grounds. They are as follows:

"The method is based upon the fact that ferrous hydrate takes up the dissolved oxygen from the water, becoming ferric; the amount of ferrous hydrate not so changed is determined with potassium permanganate. Anything then, which uses up this permanganate lowers the per cent. of dissolved oxygen found.



Siphon Water Collector for Dissolved Oxygen. A heavy piece of lead pipe was used in the construction of this apparatus in order to keep it plumb in strong currents



Apparatus Used in Determining the Amount of Dissolved Oxygen in Water. Permanent supports were used on the boat to hold the separatory funnels and a large number of analyses were made daily

This is corrected by a 'blank test,' as it is called: if, however, there are pieces of solid, easily putrescible matter, as for example, fecal matter, in the sample in which the oxygen was determined and not in the blank, these would use up the permanganate and give rise to low results for the dissolved oxygen.

"To ascertain the reliability of the Albert Levy method as well as to disarm any criticism, I would suggest that it be compared with the Winkler method as described in Richards & Woodman, 'Air, Water and Food,' page 123, which I have found accurate, and with the results obtained by actually boiling out the oxygen from the samples obtained and determining the amount of oxygen thus extracted by processes of gas analyses. From the results of this investigation it can be determined if any correction of the results already obtained is necessary and if it is advisable to replace the Albert Levy method by the Winkler."

In consequence of this report Professor Gill was requested to compare the method exactly as it was employed by the Metropolitan Sewerage Commission with the Winkler method and with the results of gas analyses made after extracting the oxygen from the samples by boiling. Samples of water were collected by the Metropolitan Commission and sent to Professor Gill in Boston, and Professor Gill collected samples himself and analyzed them.

Professor Gill's final opinion with respect to this subject is contained in a report, dated March 19, 1910; the report reads as follows:

"At your request I have made a careful study of the Albert Levy method which you employed for the determination of oxygen in the waters of New York harbor. The investigation was conducted with the idea of determining in particular the reliability of this method when compared with the results obtained by the absolute method of boiling out the oxygen dissolved in the water, and also with the results obtained by the Winkler process. From the results which I have obtained and from a critical examination of the methods as pursued by your investigators I am convinced that the Levy method as practiced by you does give the actual amount of oxygen dissolved in the sea water. It appears to me, however, that the method does not give in the hands of an unexperienced observer as concordant results as the Winkler method. However, when the Levy method is once mastered the results are thoroughly reliable."

Reagents Used. The reagents used in the analytical method employed by the Commission for the determination of dissolved oxygen* in the harbor waters were as follows:

Standard Ferrous Sulphate. This is prepared by dissolving 144 grams of Kahlbaum's crystallized ferrous sulphate in water, adding 15 cubic centimetres of H_2SO_4 and diluting the whole to three litres.

Standard Sodium Carbonate. Prepared by dissolving 30 grams of sodium carbonate crystals in one litre of water.

Standard Sulphuric Acid. Prepared by mixing equal parts of concentrated H_2SO_4 and water.

* See 5th Report Royal Commission on Sewage Disposal, Appendix VI, pp. 221-226, also Prof. W. P. Mason's volume on Water Analysis.

Standard Potassium Permanganate. Prepared by dissolving 25.4 grams of KMnO_4 in water and diluting to 4.5 litres. To be standardized against especially prepared Mohr's salt.

Collection of Samples. Samples for examination were collected in the following manner:

Water is drawn up from the required depth through a three-quarter-inch wire-bound hose by a suction pump operated by steam in the boiler room of the boat. A check valve is placed at the lower end of the rubber hose in the water to prevent an escape of water after the suction is stopped. The water passes through a glass apparatus, a, having a capacity of one litre, and then into the pump, b. After running for a few minutes the pump is stopped. A separatory funnel is filled from a rubber tube leading from the opening, c, in the collecting flask. The stop-cock at the lower end of the separatory funnel is opened slightly in order to allow the funnel to fill from the collecting flask.

For the collection of samples at points where the rubber hose could not be kept plumb, on account of the velocity of the currents, and for the collection of deep samples the apparatus shown opposite page 400 was used.

A piece of heavy lead pipe, five inches in diameter and 12 inches long, was provided with a wooden bottom. Inside of this a one-gallon glass bottle was placed and held by a wire around the neck. The bottle had a rubber stopper, perforated for two brass tubes, one tube extending one inch below the stopper and two inches above. The other tube extended to the bottom of the bottle and was connected at the top with the short tube of the separatory funnel by heavy rubber tubing.

A strip of wood one inch thick was fastened to the side of the lead pipe and to this strip was bolted a galvanized iron can four inches in diameter and ten inches high. In this can was placed the separatory funnel, into which the sample of water was collected and later analyzed. The separatory funnel rested on a wooden support or ring, fastened on the inside of the can. The end of the funnel emerged through a small opening in the cover of the can. When this wooden cover, which worked on hinges, was fastened down by the clamp at the outer side, the funnel was held firmly in place. The rubber stopper of the funnel was perforated by two brass tubes, one extending to the bottom of the funnel and one inch above the stopper, and the other one inch below the stopper and connected above with the gallon bottle by a heavy rubber tubing.

In collecting the samples the apparatus was rapidly lowered to the required depth by a one-half-inch Manila rope, marked off in feet. The water entered through the long tube of the separatory funnel and flowed through the funnel into the gallon bottle, so that when the gallon bottle was full, as indicated by bubbles of air ceasing to rise, the

separatory funnel would have been filled and emptied several times, the funnels averaging about 350 cubic centimetres in capacity. Each funnel was accurately calibrated.

Method of Making Test. The separatory funnel, after being completely filled with the water and the ground glass stopper replaced, is set up in a ring support and the contents immediately tested. Six cubic centimetres of FeSO_4 and four cubic centimetres of Na_2CO_3 are first added, both being delivered by a pipette near the bottom of the funnel. The stopper is then replaced and the contents are shaken. The dissolved oxygen, in the presence of the alkali, immediately oxidizes a portion of the dissolved salt from the ferrous to the ferric state. The ferric iron precipitates and settles to the bottom.

After a wait of five minutes the funnel is inverted and ten cubic centimetres of standard H_2SO_4 are introduced through the stem of the funnel, the stop-cock being opened. After the acid has mixed thoroughly with the other contents the funnel is allowed to stand until the mixture is nearly colorless (usually about five minutes). The contents of the funnel are then emptied into an Erlenmeyer flask and titrated with standard KMnO_4 .

A blank sample which has been collected in a similar manner is now analyzed. In this case the separatory funnel is filled as in the previous test and ten cubic centimetres of the standard H_2SO_4 are added and shaken. The six cubic centimetres of the standard FeSO_4 and four cubic centimetres of the standard Na_2CO_3 are added and shaken. The mixture is then titrated with standard KMnO_4 . In this case the acid reaction prevents the dissolved oxygen from oxidizing any of the ferrous salt to ferric with the result that the whole of the ferrous salt present is oxidized to the ferric condition by the permanganate.

By subtracting the result of titrating the first sample from that of the second the amount of ferrous salt oxidized by the dissolved oxygen in the water is obtained.

Computing Results. Results are expressed in terms of cubic centimetres of dissolved oxygen per litre of water. Suppose one cubic centimetre of permanganate equals 1.009 cubic centimetres of oxygen at 0 degrees centigrade and 760 millimetres pressure: The amount of the difference between the two titrations is multiplied by 1.009 and by 1,000 (*i. e.*, 1,009) and divided by the number of cubic centimetres of water contained in the funnel.

Standard Units. The quantity of dissolved oxygen in the different samples collected was determined in terms of cubic centimetres per litre and the percentage of saturation of each sample was calculated from a diagram for sea and land waters, issued by the Royal Commission on Sewage Disposal of Great Britain, showing the saturation figures at different temperatures and percentages of sea-water.

Locating Sampling Points. When a sample was collected the point of collection was noted with reference to points on shore, or readings were made with the sextant to locate the exact position when the collecting point was at a distance from the shore.

At the same time observations were made of the time of taking the sample, the direction of the tidal currents, the direction and velocity of the wind, the depth of the water, the depth at which the sample was taken, the temperature and the specific gravity of the water from which the percentage of land water was computed.

The average percentage of saturation with oxygen and the average number of cubic centimetres of oxygen per litre during the period from June 1 to October 5, 1909, in the various sections of New York harbor were computed to show the difference between the amount during ebb and flood tides. There were 787 analyses included in these averages.

The average percentage of saturation with oxygen and the average number of cubic centimetres of oxygen per litre during the same period in the various sections were computed to show the difference between the number at the surface and at the bottom. There were 722 analyses included in these averages.

Tabular Summary of Data. For convenience the tidal waters about New York were divided into several separate sections and the average percentages of saturation for each section are given in Tables II and III, which contain, for the different depths and for the flood and ebb currents, the amount of dissolved oxygen in cubic centimetres per litre and the percentage of saturation, with the number of analyses upon which the averages were based.

In calculating the averages for any section all the samples taken in that section were used, except that in the cases of Gravesend and Jamaica bays those samples collected near sewer outlets were not used. Representative samples were taken at all parts of a section. Samples taken near shore were obtained outside the pierhead line, not in the slips.

DISSOLVED OXYGEN IN THE WATERS OF THE UPPER BAY

Surface and Bottom. The difference between the amount of oxygen at the surface and at the bottom of the Upper bay was very small, but there was a decided difference between the amount in the samples taken during flood and those taken during ebb currents.

Ebb and Flood Tides. Taking an average of all the samples collected during the flow of the ebb currents, the water of the Upper bay showed a deficiency in oxygen amounting to 36 per cent. An average of all the samples taken during the flow of the

flood currents showed a deficiency of 22 per cent. The waters of the Upper bay at no time averaged more than 78 per cent. of the oxygen which they should have had even after receiving the large quantities of sea water from the Lower bay. During the half of the 24 hours of each day when the Hudson and East rivers were emptying their contents into the bay, the amount of oxygen was only 64 per cent. of what it should have been.

Local Deficiencies. There was a decided reduction below the average in the amount of oxygen in the water of the bay opposite the outlet of Gowanus canal and near the outfall of the large trunk sewer at the foot of Sixty-fifth street, Brooklyn, showing the effect of the sewage contamination at these points.

EAST RIVER

(FROM GOVERNOR'S ISLAND TO HELL GATE)

Surface and Bottom. The difference between the amount of oxygen at the surface and at the bottom of the East river below Hell Gate was small. The surface samples usually contained a slightly smaller amount of oxygen than those taken lower down.

Ebb and Flood Tides. An average of all the samples taken during the flood compared with those taken during the ebb currents showed that there was a greater deficiency in the oxygen of the East river during the ebb than during the flood. During the flood the water contained 69 per cent. while the water flowing out toward the bay contained only 60 per cent. of the oxygen which it should have had.

Local Deficiencies. There was a considerable reduction below the average in the amount of oxygen in the river at certain points, notably opposite the mouth of Newtown creek and off Wallabout bay.

EAST RIVER

(FROM HELL GATE TO THROGS NECK)

Surface and Bottom. The difference between the amount of oxygen at the surface and at the bottom of the East river above Hell Gate was very small.

On Ebb and Flood Tides. The entrance of the comparatively unpolluted water of Long Island Sound into the East river on the ebb currents is shown by the high average percentage of oxygen saturation—92 per cent.

The water coming from the lower section of the East river toward the Sound on the flood currents contained 80 per cent. of the amount of oxygen which it should have had.

DATA COLLECTED

HUDSON RIVER

(FROM ITS MOUTH TO SPUYTEN DUYVIL CREEK)

Surface and Bottom. The difference between the amount of dissolved oxygen at the surface and at the bottom of the Hudson river below Spuyten Duyvil creek was slight. The samples taken near the surface usually contained a somewhat smaller amount of oxygen than those taken at the bottom.

On Ebb and Flood Tides. An average of all the samples taken during the flood compared with those taken during the flow of the ebb currents, showed that there was a greater deficiency in the oxygen of the Hudson river below Spuyten Duyvil during the ebb than during the flood. During the flood the water contained 76 per cent. while the water passing down toward the bay contained only 66 per cent. of the oxygen which it should have had.

HUDSON RIVER

(FROM SPUYTEN DUYVIL TO YONKERS)

Surface and Bottom. In the section of the Hudson above Spuyten Duyvil there was slightly more oxygen at the surface than at the bottom, possibly because the more polluted sea water had a tendency to remain at the bottom.

On Ebb and Flood Tides. The samples taken on the ebb current showed about the same deficiency in oxygen as those taken on the flood, or about 16 per cent.

The ebb currents carried much of the Yonkers sewage down the river near the eastern shore and the path of this sewage could be traced as far down as Inwood, about four miles, by the dissolved oxygen tests. As some of the samples taken on the ebb tide were from this polluted field, the average per cent. of oxygen saturation for this upper section of the Hudson on the ebb is probably a little too low.

HARLEM RIVER

Surface and Bottom. There was very little difference between the amount of oxygen at the surface and at the bottom of the Harlem river and the general average of oxygen for the flood tide agreed pretty closely with that for the ebb.

On Average of Tides. The average for all tides and all depths showed that the oxygen in the Harlem river was nearly 50 per cent. exhausted.

Eastern End of River. There was a decided reduction below the average in the amount of oxygen at the eastern end of the river between Hell Gate and the Third Avenue Bridge. Here the water often contained only 20 per cent. of the amount of oxygen which it should have had.

This part of the river does not seem to be flushed out thoroughly by the flow from the East river on the ebb tide. In fact the water contains more oxygen, as a rule, after the flow of the flood currents from the Hudson.

The average of a series of samples showed a deficiency in oxygen of 73 per cent. on the ebb tide and of 57 per cent. on the flood.

KILL VAN KULL

Surface and Bottom. A comparison of the amount of oxygen at the surface and at the bottom of the Kill van Kull showed a somewhat larger amount at the bottom.

On Ebb and Flood Tides. The amount of oxygen present in the water during the flow of the flood currents was 82 per cent. of what it should have been, as compared with 78 per cent. on the ebb. The larger amount of oxygen at the bottom is probably explained by the less polluted and heavier sea water remaining at the bottom.

NEWARK BAY

On Ebb and Flood Tides. The water of Newark bay contained rather more oxygen on the flood tide, after the water from the Kill van Kull and the Arthur Kill had mixed with it, than on the ebb when it received the waters of the very polluted Passaic river.

The water in the bay is very shallow and not much difference was found between the amount of oxygen at the surface and at the bottom.

PASSAIC RIVER

At Lower Limits of Newark. The amount of oxygen in the Passaic river varied greatly according to the point where the samples were taken. At a point just below the Pennsylvania Railroad bridge, near the foot of New Jersey Railroad avenue, Newark, the water on one day was found to contain no oxygen at all, either during the flood or the ebb currents. On another day it was 90 per cent. exhausted during the ebb and 86 per cent. during the flood.

At Mouth. The water at the mouth where the river was flushed by the flood currents from Newark bay had a better supply of oxygen, so that the average for all the samples taken showed that the river had about 27 per cent. of the oxygen which it should have had.

Effects of Water on Paints. The water of the Passaic at Newark was black and had a strong odor of hydrogen sulphide. The white paint on boats which had tied up here had turned a dark gray or black, from the formation of sulphide of lead.

ARTHUR KILL

Surface and Bottom. During the flood tide the water from Raritan bay partly flushes out the Arthur Kill and no deficiency was found in the oxygen present in the water during this period.

The influence of the heavier and purer sea water was also seen in the higher percentage of oxygen in the deep samples than in those taken at the surface.

On Ebb and Flood Tides. During the flow of the ebb currents the water from the Rahway river and the polluted water from Newark bay and Kill van Kull, containing the Orange sewage, which is discharged into the Kills at Elizabethport, entered the Arthur Kill and reduced the amount of oxygen present to 73 per cent. of what it should have been.

THE NARROWS

Surface and Bottom. At the Narrows the samples of water taken at the bottom, in most cases at the depth of 60 feet, contained less oxygen than those taken at the surface.

On Ebb and Flood Tides. The difference between the water at this point on the flood and ebb tides was very marked. The sea water entering from the Lower bay raised the percentage of oxygen here, so that it averaged 92 per cent. of what it should have been. The polluted water from the Upper bay passing out lowered the percentage of oxygen, so that the water contained only 74 per cent. of the amount which it should have had.

GRAVESEND BAY

Surface. Owing to the shallowness of Gravesend bay none but surface samples were taken. The average of these oxygen figures showed a deficiency of 10 per cent. Those samples taken near the outlet of the effluent pipe from the Coney Island sewage disposal plant were not included in the averages.

The average amount of oxygen in the water during the flow of the flood currents was 85 per cent. of what should have been present.

LOWER BAY

Surface and Bottom. The difference between the amount of oxygen in the water at the surface and at the bottom of the Lower bay was quite marked. The polluted water from the Upper bay, of a lower specific gravity, had a tendency to keep near the

surface as it passed into the Lower bay so that while the water at the bottom of the Lower bay was saturated with oxygen, the water at the surface had a slight deficiency, averaging about ten per cent.

Deep Samples. Samples taken in very deep spots in the ocean, in the so-called mud gorge, ten miles off Long Branch, were saturated with oxygen, while surface samples taken at the same points were also found to be saturated.

SUMMARY

As a rule there was not much difference between the amount of oxygen in the water at the surface and in that at the bottom. In sections where the water was badly polluted the surface samples usually contained a slightly smaller amount of oxygen than did the deep samples, due, perhaps, to the presence of bacteria of decomposition, in the surface water, which consumed a proportionately larger amount of its oxygen. Often, too, the purer sea water, which had a tendency to remain at the bottom by reason of its higher specific gravity, increased the quantity of dissolved oxygen at the bottom above that at the surface by dilution.

Where the water was comparatively pure the very deep samples usually contained a smaller amount of oxygen than those taken at the surface.

When comparatively unpolluted water such as that from the Lower bay and the Sound entered a polluted section of water the percentage of oxygen was raised by the dilution.

When sewage or a polluted water entered a comparatively unpolluted section of water, the percentage of oxygen saturation was lowered by dilution, by the addition of easily oxidizable substances which caused a more or less rapid loss of its dissolved oxygen and by the addition of organic constituents of sewage, not readily oxidizable, which were oxidized by the bacteria present in the water and which indirectly caused a loss of the dissolved oxygen.

The amount of oxygen was less in the water near shore than in the water nearer the middle of the river or bay, and there was a decided reduction below the average amount when the outfall of a sewer was approached.

TABLE I

VOLUMES OF OXYGEN ABSORBED FROM THE AIR BY DISTILLED WATER AND BY SEA WATER
AT DIFFERENT TEMPERATURES CENTIGRADE AND AT A PRESSURE OF 760 M. M.

FROM THE FIFTH REPORT OF THE ROYAL COMMISSION ON SEWAGE DISPOSAL, VOL. 18, 1908.

Temperatures in Degrees Centigrade	Percentages of Distilled Water to Sea Water															
	0	4	8	12	16	20	24	28	32	36	40	44	52	64	72	100
17	5.6	5.6	5.7	5.7	5.8	5.9	5.9	6.0	6.0	6.0	6.1	6.2	6.3	6.4	6.5	6.9
18	5.5	5.5	5.6	5.6	5.7	5.8	5.9	5.9	5.9	6.0	6.0	6.0	6.2	6.3	6.4	6.8
19	5.4	5.4	5.5	5.5	5.6	5.6	5.7	5.8	5.8	5.8	5.9	6.0	6.0	6.2	6.3	6.7
20	5.3	5.3	5.4	5.4	5.5	5.5	5.6	5.7	5.7	5.8	5.8	5.8	5.9	6.0	6.2	6.5
21	5.2	5.2	5.3	5.3	5.4	5.4	5.5	5.5	5.6	5.6	5.7	5.7	5.8	6.0	6.1	6.4
22	5.1	5.1	5.2	5.3	5.3	5.4	5.4	5.5	5.5	5.6	5.6	5.6	5.7	5.8	5.9	6.3
23	5.0	5.0	5.1	5.1	5.2	5.2	5.2	5.3	5.4	5.4	5.6	5.6	5.6	5.8	5.9	6.2
24	4.9	4.9	5.0	5.0	5.1	5.2	5.2	5.3	5.3	5.4	5.4	5.4	5.5	5.6	5.7	6.1
25	4.9	4.9	5.0	5.0	5.1	5.1	5.2	5.2	5.2	5.3	5.4	5.4	5.5	5.6	5.7	6.0
26	4.8	4.9	4.9	5.0	5.0	5.1	5.1	5.2	5.2	5.2	5.3	5.3	5.4	5.5	5.6	5.9



The Figures in Circles Show the Per Cent. of Dissolved Oxygen in the Waters in the Localities Shown by Shading

TABLE II

AVERAGE AMOUNT OF DISSOLVED OXYGEN IN THE WATER DURING EBB AND FLOOD CURRENTS, JUNE 1 TO OCTOBER 5, 1909.

Location of Samples	Tides					
	Ebb Currents			Flood Currents		
	Number of Analyses	C. C. Per Litre	Per Cent. of Saturation	Number of Analyses	C. C. Per Litre	Per Cent. of Saturation
Upper bay.....	42	3.60	64	24	4.91	78
Hudson river, below Spuyten Duyvil	29	3.67	66	68	4.63	76
Hudson river, above Spuyten Duyvil	10	5.13	83	22	5.01	84
East river, below Hell Gate.....	77	3.46	60	78	4.03	69
East river, Hell Gate to Long Island Sound.....	18	5.38	92	21	4.66	80
Long Island Sound, near Throgs Neck.....	3	5.90	100	5	5.78	98
Harlem river.....	30	3.28	56	22	3.21	55
Kill van Kull.....	40	4.49	78	24	4.76	82
Newark bay.....	12	4.21	74	13	4.41	78
Passaic river at Newark.....	4	0.30	5	4	0.42	7
Arthur Kill.....	16	4.31	73	8	5.61	100
Narrows.....	17	4.16	74	15	5.18	92
Gravesend bay.....	..	....	..	10	5.00	90
Lower bay.....	59	5.29	95	44	5.56	100
Rockaway inlet.....	6	5.10	93	6	6.14	100
Jamaica bay.....	18	4.06	73	11	4.26	81
Atlantic ocean, ten miles off Long Branch.....	..	....	..	4	6.05	100
Gowanus canal.....	2	0.00	0	..	....	..
Newtown creek.....	..	....	..	3	0.00	0
Wallabout canal.....	1	0.30	6	..	....	..

Note. In calculating the above averages, all the samples collected in the various sections were included, except that in the cases of Gravesend and Jamaica bays, those samples collected near sewer outlets were not used.

TABLE III

AVERAGE AMOUNT OF DISSOLVED OXYGEN IN THE WATER AT THE SURFACE AND AT THE BOTTOM, JUNE 1 TO OCTOBER 5, 1909.

Location of Samples	Depths					
	Surface			Bottom		
	Number of Analyses	C. C. Per Litre	Per Cent. of Saturation	Number of Analyses	C. C. Per Litre	Per Cent. of Saturation
Upper bay.....	28	3.76	66	28	4.15	69
Hudson river, below Spuyten Duyvil	41	4.17	71	38	4.30	73
Hudson river, above Spuyten Duyvil	15	5.11	84	15	4.96	82
East river, below Hell Gate.....	65	3.63	64	65	3.83	66
East river, Hell Gate to Long Island Sound.....	19	5.01	86	19	4.99	85
Long Island Sound.....	3	5.69	97	3	5.92	100
Harlem river.....	26	3.21	55	26	3.28	56
Kill van Kull.....	28	4.37	78	28	4.74	81
Newark bay.....	12	4.29	76	12	4.37	77
Passaic river at Newark.....	4	0.33	6	4	0.40	7
Arthur Kill.....	12	4.52	80	12	4.81	84
Narrows.....	16	4.86	87	16	4.55	80
Gravesend bay.....	10	5.00	90	..	....	..
Lower bay.....	56	5.23	90	46	5.61	100
Rockaway inlet.....	6	5.58	96	6	5.68	98
Jamaica bay.....	20	3.96	74	9	4.52	82
Atlantic ocean, ten miles off Long Branch.....	2	6.21	100	2	5.89	100
Gowanus canal.....	2	0.00	0	..	....	..
Newtown creek.....	3	0.00	0	..	....	..
Wallabout canal.....	1	0.30	6	..	....	..

Note. In calculating the above averages, all the samples collected one foot under the surface and those collected one foot above the bottom were included except that in the cases of Gravesend and Jamaica bays those samples collected near sewer outlets were not used. Those samples collected at depths between the surface and the bottom were not included.

CHAPTER IX

EVIDENCE OF POLLUTION IN THE DEPOSITS ON THE BOTTOM OF THE HARBOR

METHODS OF IDENTIFYING MATTERS OF SEWAGE ORIGIN

Bacterial Evidence of Pollution. Prior to 1908 bacterial and chemical analyses had been made of deposits upon the bottom of New York harbor, but the information which these examinations furnished lacked definiteness as to the presence or absence of sewage matter. The work here described was undertaken in order to make this information more definite and complete.

About 700 samples of solid matter were examined by the Metropolitan Sewerage Commission before 1908 for the number of bacteria which were contained—the results ranging from 7,500 to 26,000,000 bacteria per gram. In one case 400,000 bacteria were found in a sample close to another sample which contained 19,000,000. Comparing one section with another, the bacteria in the material at the harbor bottom were numerous in the Upper bay and in that section immediately west of the Brooklyn shore, and it is to be noted that they were usually most numerous where the pollution was most intense. But it was impossible to say how many bacteria would have been present in the absence of sewage matters.

Colon determinations to the number of 322 had been made of material from the bottom. In nearly all these cases the organism was found according to the presumptive test. But this test is no longer regarded as conclusive, nor is the presence of colon bacilli looked upon as certain proof of the presence of sewage. There had been 566 samples of solid matter in the harbor bottom analyzed for loss on ignition. But this test did little to make it plain whether the deposits were composed of sewage matters or not. No examinations had been made of mud from the uncontaminated places.

Identification of Soap, Fats and Animal Debris. In seeking more definite information concerning the condition of the harbor bottom with reference to pollution by sewage, the Metropolitan Commission after 1907, considered the impossibility of placing implicit faith in chemical and bacterial analyses as ordinarily made, and sought to supplant this work by examinations which would not be so easily influenced by the presence of such substances as sea weed, the bodies of marine animals and other unwholesome forms or remains of life. On October 7, 1908, a letter was sent by the Commission to James H. Stebbins, Ph. D., a well known microscopist and chemist, requesting him to advise with the Commission as to methods and analytical technique. The Commission was particularly interested to know whether it could be made profitable to



The Shaded Areas Indicate Where the Bottom Mud was Found to be Most Heavily

examine water and solid deposits from the harbor for soap and grease, fibres of paper and debris of animal origin peculiar to human occupation. At the same time a number of samples of solid matters dredged from the harbor bottom were sent to Dr. Stebbins for study.

Dr. Stebbins' reply was to the effect that the only manner of detecting small quantities of soap or grease which would be practicable to employ upon the large scale required in the Commission's work, would be to first extract the fats from the sample with ether and identify their presence under the microscope, then acidify with hydrochloric acid and extract the fatty residue with ether and note the result under the microscope. The test could not be made quantitative without involving a regular chemical examination, but a fair idea of the fats and fatty acids present could be formed by observing the quantity or residue left upon the microscopic slide after evaporation of the ether.

Microscopic Examinations. In Dr. Stebbins' opinion it would not be a difficult matter, after a little practice, to identify the various fibres of paper, etc., by means of microscopic examinations. Such debris as animal muscle, fibres and connective and elastic tissues, ova of animal parasites and hairs promised to furnish valuable diagnostic factors.

A scheme for examining harbor sediments was worked out by Dr. Stebbins and employed by him for the examination of a number of samples of deposits which the Commission collected especially for his use. The method is given here in full, for, although it was not found feasible to employ it in the large number of routine examinations made necessary by the nature of the Commission's work, the scheme may be of service to other investigators.

Methods of Microscopic Analysis; First Operation. Shake up a small portion of the sediment in a test tube with water. Allow the coarser and heavier particles to settle, and decant the fine and light matter into another test tube before it has time to subside. Examine a few drops of the decanted liquid upon a slide microscopically with one-half and one-eighth inch objectives and No. 3 ocular.

If contamination by sewage is suspected, look for any of the following: Ciliated infusoria such as paramaecium, trachelocera, fungous forms such as mold hyphae Saprolegnia, Leptothrix, Beggiatoa (Sulphur-forming organism), and miscellaneous objects such as starch grains, yeast cells, pollen, fibres of wood, paper, muscle, elastic and connective tissue fibres, epithelial cells, threads of silk, wool, cotton and linen; insect scales, feather barbs, the eggs of certain parasitic worms, such as Taenia solium, Ascaris lumbricoides, Trichocephalus dispar, Uncinaria americana, etc., seeds of wheat, oats, etc.

It may, furthermore, be well to look for *Euglena viridis*, which though not regularly occurring in sewage, nevertheless feeds upon decaying vegetable matter, and consequently may be associated with it in polluted water and its sediments.

Second Operation. Add ether to the test tube containing the light decanted matter, warm gently, shake up well, and allow to settle into two layers. Evaporate a few drops of the ethereal layer upon a slide, and note whether any residue is left upon the same. Any oily, semi-solid, or solid residue remaining will represent neutral fat present in the original river sediment, and according to its nature it may have been derived from lard, butter, cocoanut oil, tallow, etc., and hence would indicate contamination by organic animal or vegetable matter, or perhaps both.

Acidify the ethereal solution remaining in the test tube strongly with hydrochloric acid. Warm gently, shake well, and allow the mixture to separate into two layers. Pipette off a few drops of the ethereal layer, place the same upon a slide, and allow to evaporate to dryness, and examine any residue remaining microscopically with one-half and one-eighth-inch objectives, and No. 3 ocular.

If a crystalline or semi-crystalline residue remains upon the slide, it is likely to consist of fatty acids derived from the decomposition of soaps present in the original river, or harbor sediment.

Treat the residue upon the slide with a few drops of alcohol, warm gently, and note whether the residue dissolves. If soluble, test the alcoholic solution with blue litmus paper. If the paper turns reddish, either while wet or after the alcohol has evaporated, the presence of fatty acids is clearly indicated. As a further evidence of their presence, allow the alcoholic solution to evaporate upon the slide, and examine the residue under the microscope, when usually either a crystalline, or semi-crystalline white, to whitish residue will be left upon the slide. Occasionally oily fatty acids such as oleic acid may be obtained according to the nature of the soap from which they were derived, and in such cases the residue will be oily instead of crystalline. Hence the presence of fatty acids will clearly indicate the presence of insoluble soaps in the river or harbor sediment, and consequently contamination by sewage.

Place a small quantity of the heavier matter separated by decantation from the lighter matter upon a slide, cover it with a cover glass, and examine it microscopically for any of the vegetable or animal matter, etc., previously alluded to.

If any of the organisms, fibres, seeds, etc., previously mentioned are found, contamination by sewage is clearly indicated.

To the test tube containing the heavy material add ether, heat gently and shake up well, and allow to cool, and separate into two layers. Note whether the ethereal solution has changed color; if it has, it may contain neutral fats.

Pipette off a few drops of the ethereal solution, place them upon a slide, and examine them under the microscope. If a residue consisting of white, or slightly colored warty concretions, nacreous plates, or fern-shaped crystals, is obtained, neutral animal or vegetable fats, or both, are present, and clearly indicate contamination by sewage.

The heavy residue may also contain soaps which were not entirely removed by the first treatment by decantation.

To ascertain whether soap is present, treat the residue remaining as follows:

Decant or pipette off the ethereal neutral fat solution, add excess of hydrochloric acid, and treat as in second operation. A white or slightly colored crystalline, or semi-crystalline residue remaining would indicate fatty acids and hence soap in the original sediment under examination.

A number of samples were examined by Dr. Stebbins, a statement of the results of which are given below. The conclusions drawn from the examinations were apparently fully justified by other information in possession of the Commission.

SUMMARY OF RESULTS OF MICROSCOPICAL EXAMINATIONS OF RIVER AND HARBOR SEDIMENTS, BY DR. J. H. STEBBINS

Sample No. 657, from Harlem River Between Third and Fourth Avenues. Found: Much argillaceous matter, and sand. A few dead diatoms. Particles of wood, vegetable epidermis, some trichomes, a little muscle tissue, two eggs of *Taenia solium*, a few pollen grains, fibres of cotton, wool and flax (toilet paper), several *Crenothrix* filaments, and some small particles of mica.

The specimen also contains an appreciable quantity of neutral fat, and fatty acids (soap).

Conclusions. This sample is clearly contaminated with fecal matter, house washings, etc., in other words, sewage. ^W

Sample No. 319, from West Sixty-ninth Street, Hudson River. Large Sewer at Sixty-sixth Street. Found: Much argillaceous matter, humus, numerous diatoms, one Rhizopod, spicules, considerable vegetable epidermis, bast fibres, and fibro-vascular bundles, threads, a little cotton, wool, and linen fibre (toilet paper), wheat hairs, *Crenothrix* filaments, and considerable muscle tissue, and fibres (meat).

Some neutral fat, and fatty acids (soap) are also present.

Conclusions. This sample is markedly contaminated with sewage.

Sample No. 491, from Wallabout Canal, East River, With Sewer at Head of Canal.

Found: Much argillaceous matter, humus, numerous diatoms, some spicules, considerable linen, and straw fibre, vegetable epidermis, wheat hairs, and Conferva filaments, the skeleton of a Crustacean, probably Cypris, or Daphnia, a few bits of thread, and filaments, considerable muscle tissue, and fibres (meat). Considerable neutral fat, and a small quantity of fatty acids (soap).

Conclusions. This sample is also clearly contaminated with sewage.

Sample No. 3, Marked from Intersection of Center Line of Pier A and Center Line of Hudson River. Considerable argillaceous matter, humus, moderate number of linen, and straw fibres, vegetable epidermis, and other portions of vegetable matter, Crenothrix, a few diatoms, particles of shell, sand, and some muscle fibre, and one elastic fibre. Small quantity of neutral and fatty acids.

Conclusions. This sample is contaminated with sewage, but to a lesser degree than the samples previously examined.

Sample No. 3, Marked from Intersection of Center Line of Broad Street, East River, and 150 Feet from End of Pier. Found: Meat, woolen, and linen fibres are absent, but, on the other hand, the sediment was found to consist almost wholly of living and dead algae, numerous protozoa, and a few crustacea, as follows: Protozoa—Colpidium, one; Enchelys, numerous; Vorticella, a few; Rotifera, Asplanchna, and Mastigocera, a few; Crustacea, Cypris, and Bosmina, a few; Diatoms, quite numerous; Conferva, Ulothrix, and Cladothrix, quite plentiful; Rhizoclonium salinum, abundant; Urococcus hookerianus, abundant; Schizomeris leibleinii, abundant; Oogonia of Vaucheria thurettii, numerous; Eudorina stagnale, moderate number; Plant epidermis, considerable, and numerous other unidentified algae, and several unidentified infusoria. Sand, slag, and some argillaceous matter. Neutral fats, and fatty acids (soap) present in very small quantity.

Conclusions. This sample seems to be only slightly contaminated with sewage. The contamination seems to be more in the nature of house washings, etc., than fecal matter (absence of muscle).

Water Sample No. 3, Marked from Intersection of Center Line of Broad Street and 50 Feet Beyond End of Pier. Found: Enchelys, and numerous unidentifiable infusoria. Considerable vegetable epidermis, Oogonia of Vaucheria thurettii, several Conferva filaments, a few cotton and linen fibres, one trichome, and numerous small fat globules; a little sand, and argillaceous matter, but no fecal matter (muscle).

The amount of sediment was so small that no test for the presence of soap could be made.

Conclusions. This sample does not seem to be contaminated by fecal matter, but the presence of the fat globules would point to a slight contamination with sewage other than fecal matter.

Sample No. 2, Marked from off Erie Basin. Found: Numerous small worms resembling round worms, or Nematodes. Numerous diatoms, Oogonia, Conferva filaments, bits of wood, considerable plant epidermis. Ulothrix, Botryococcus braunii, Schizomeris leibleinii, Enteromorpha intestinalis, Grass glumes, Urococcus hookerianus, a little muscle tissue (meat), a few spicules, and linen fibres. Sand, argillaceous matter, bits of shell, humus considerable, and a few human hairs.

The sample also contains a small quantity of neutral fat, and fatty acids (soap).

The sample smells very foul, the smell strongly resembling carrion.

Conclusions. This specimen is evidently contaminated with fecal, decaying animal and vegetable matter, wash-water, etc.

Sample No. 2, Marked from Kill van Kull. Found: A few diatoms, some plant epidermis, and bits of wood, Conferva filaments, Oogonia, a little muscle fibre, spicules, and much sand and argillaceous matter, and humus.

There is also present a small quantity of neutral fat, and a trace of fatty acids.

Conclusions. This sample is somewhat contaminated with sewage, but more particularly with fecal, and animal matter, than with soap.

Sample No. 2, Marked from Great Kills. Found: Much sand and argillaceous matter, and humus. A few minute stems of plants, diatoms, Conferva filaments, plant epidermis, Leptothrix, grass glumes, and a few cotton, and linen fibres.

Neutral fats, and fatty acids, are absent.

Conclusions. From the above, it does not appear that the sample is contaminated with sewage.

The examination of eighteen other samples collected in December, 1908, led Dr. Stebbins to modify his opinion as to the importance of neutral fats as a diagnostic factor in the examination of sediments for sewage matters. The later samples were collected from uncontaminated places and upon examination showed no pollution with fecal matter, yet they all contained neutral fats in some amount. From this fact Dr. Stebbins inferred that a very small amount of neutral fats was a normal constituent of all salt and brackish water sediments.

EXAMINATIONS BY THE METROPOLITAN SEWERAGE COMMISSION

Owing to uncertainties connected with the determination of fats and grease in the deposits, and particularly in making such tests quantitative, the Commission decided

to confine its examinations to the microscope. The method employed was somewhat similar to that reported in 1883 by Dr. H. J. Sorby to the British Royal Commission on Metropolitan Sewage Disposal, as a result of an exhaustive microscopic study of Thames river mud for evidence of pollution.

Dr. Sorby's method consisted in straining out the suspended mud in a known volume of river water and counting the number of muscle fibres, hairs and spiral vessels. These small particles he considered to have come from domestic sewage or street sweepings. The number which occurred in a given volume of water was taken to indicate the degree of pollution. Dr. Sorby decided it was useless to examine the very fine particles, or the coarser fragments for evidence of pollution and confined his attention to the few kinds of particles intermediate in size, easily recognized and of known composition.

Method of Examination Adopted by Metropolitan Sewerage Commission. The procedure adopted by the Metropolitan Sewerage Commission of New York consisted of two parts:

- (1) Observation of the color, odor and composition of the sample when collected; and
- (2) A search for microscopic debris which had probably come from sewage.

Collection of Samples. The samples were collected from one of the Commission's boats. An oyster boat with a large roomy deck, low freeboard and ample beam to give steadiness having been found especially suitable for this purpose. The samples were collected in accordance with a prearranged scheme by which it was intended to cover practically the whole area of the harbor bottom. Samples were located by means of sextant observations, upon previously established land marks, or, where very near the shore, convenient ranges were employed.

Surface Samples. The mud samples from the surface of the harbor bottom were collected by means of small iron dredges, shaped like a mushroom. The dredge consisted of an iron rod, two feet three inches long, set firmly in the apex of a plate-iron cone which was six inches deep and 12 inches across the open base, shown opposite page 424.

This mushroom dredge was dragged over the surface of the mud until the cone was partly filled. It was then raised and a pint sample of mud was spooned out into a glass fruit jar. Before washing the remaining mud out of the dredge, notes of the color, odor and composition of the dredged material were made. Frequently a thin, light brown color was observed overlying a dark brown or black sub-soil, showing, as

experience taught, that the surface of the mud had been well supplied with oxygen while the interior was in a putrefying condition.

Subsurface Samples. Subsurface samples of mud were obtained by a pipe mud borer. The mud borer consisted of an iron half-pipe, two inches in internal diameter and 11 feet long. There was a reducer at one end into which lengths of one-inch pipe could be screwed to serve as a handle.

Mud borings were obtained by pressing down on the handle of the borer until the half-pipe was thrust to the desired depth in the mud. The borer was then hoisted up aboard the ship from which it was being operated and samples of the boring were spooned out of the half-pipe. It was necessary to scrape off and discard the outer layer of mud along the entire length of the mud, to prevent the contamination of subsurface mud with the surface mud, through which it had been withdrawn.

Preparation of Samples for Examination. The examination of mud samples in the laboratory was carried on as follows:

- (1) The microscopic particles or debris were washed free from mud.
- (2) The debris was placed in a large petri dish over a white porcelain slab.
- (3) The particles which seemed likely to prove of interest were picked out and identified.

In polluted samples the debris was generally so black with ferrous sulphide that it was necessary to decolorize the particles in ten per cent hydrochloric acid. Mounts for microscopic examination were made in glycerine.

To wash the debris free from mud the analyst filled the glass jar containing the mud samples, stirred with a glass rod and poured the suspended mud out upon a perforated porcelain plate fitting snugly in an agateware fruit-jar funnel. The mud was washed out through the perforations and the clean debris was washed off of the plate into a small glass pitcher. This process was repeated until the required amount of debris had been obtained. The analyst then proceeded to examine the debris and write out his report before beginning a second analysis.

The porcelain plate used was two and three-fourths inches in diameter, and the perforations were between one-twentieth and one-fortieth of an inch in diameter.

Later faster progress was made by washing out ten to fifteen samples in succession and then setting aside the washing apparatus and examining the debris. Also, to some extent, the method of washing out the sample was changed. The entire contents of the jar in which the sample had been collected was washed out upon a copper sieve with meshes one-twentieth of an inch apart; all but the coarsest particles of sand and debris of a size suitable for examination passing through. Then the sieve was inverted

over the jar funnel and the debris washed into a large glass pitcher. By agitating the pitcher and pouring out quickly upon the porcelain plate the useful debris were obtained free from mud. By this method a sample could be made ready for examination in less than eight minutes. The number of samples which could be examined in a day by one operator was 23.

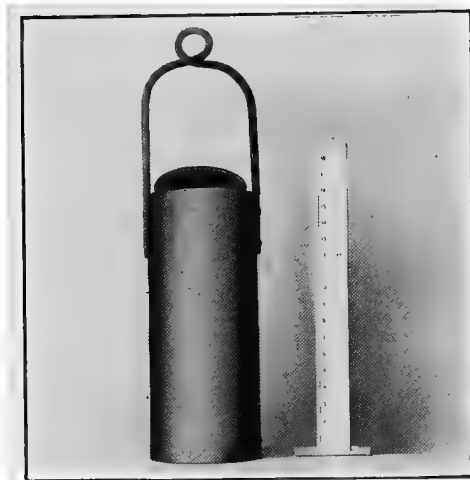
The debris selected for examination, if the sample was from a polluted place, contained such substances as bits of paper, glumes, straw, small roots, animal hairs, coal, pieces of twine, tufts of wool or of cotton. These objects were transferred to a watch crystal containing ten per cent. hydrochloric acid. In a short time the objects became clear enough to be mounted upon a glass slide for identification by means of a microscope. Glycerine diluted with 50 per cent. alcohol was used as a mounting fluid for rapid work, it being found that objects cleared quickly in it. Clinging to the microscopic objects just mentioned were other objects of much significance. Thus, muscle fibres could be found, bits of starch parenchyma, fragments of seed coats, animal tissues, etc.

Methods of Examination. The identification of the debris required less and less use of the microscope, as the microscopic appearance of the particles of diagnostic value became more and more familiar, but in practically every case the diagnosis of pollution was supplemented by a microscopic examination. The microscope used was a Spencer with a one and one-quarter inch eye piece and three objectives of one-sixth, one-third and two-thirds focal length, giving magnifying powers of 530, 250 and 118 diameters respectively.

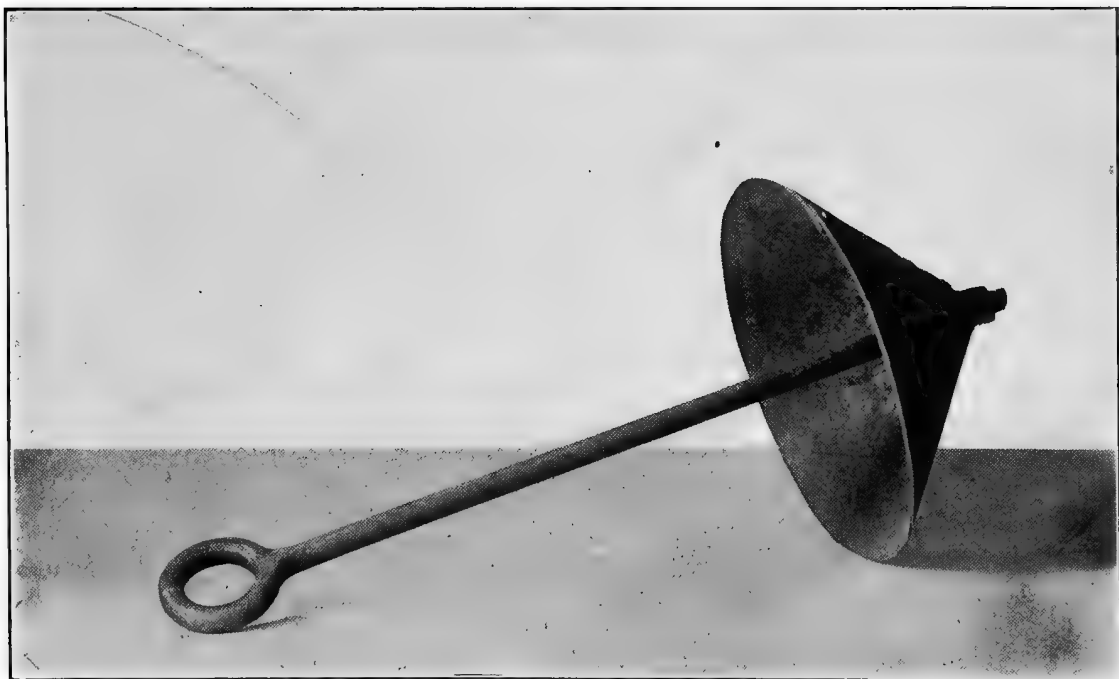
A dozen permanent mounts of debris from various parts of the harbor were made for study and comparison. Study was also made of a collection of vegetable and animal fibres, debris from feces and manure and city sewage.

The objects found, together with the data which were collected when the samples were gathered and observations made during the washing process, constituted the basis for a conclusion as to the pollution of a sample. When, as a result of the straining, no debris was found, and if the sample looked clean when collected and did not become foul before examination, it was considered to be an unpolluted sample. Whether pollution could be detected by other methods such as chemical or bacterial tests was not considered in drawing a conclusion.

Evidence of Pollution. The most persistent evidences of pollution were bits of paper and glumes. These came to be regarded as prima facie evidence of pollution. They were almost invariably associated with polluted samples and absent from the samples which were from their evidence judged to be unpolluted. In the samples coming from the region of a sewer outfall, or where sewage debris tended to collect in



Ooze Collector. The escape of soft material is prevented by valves in top and bottom



Dredge Used to Obtain Samples of Harbor Bottom for Analysis

quantity, the presence of small seeds was expected. Small roots and root fragments were to be found in most samples. Starch parenchyma came, as a rule, from plant organs, such as fleshy roots, stems, seeds, fruits, etc. It was taken to indicate garbage or undigested plant substances and food.

In some samples what was termed natural debris was abundant. This represents the remains of various plant organs, such as fragments of roots, stems, leaves, bark, which come from vegetation growing perhaps near where these samples were collected.

The presence or absence of other indications of pollution helped the decision as to whether the debris was natural or not. The location of the sample and observations taken at the time of collection were all a part of the evidence which was weighed in coming to a conclusion as to the pollution of the mud.

General Condition of Harbor Bottom. The mud examinations made, of which there were altogether 1,100, showed that a large part of the bottom of New York harbor was polluted with deposits of solid matter from sewage. The bottom of the Upper bay was generally polluted, although the Jersey flats west of a line from Constable Hook to Black Tom Island were found to be singularly free from sewage deposits. The bottom near Manhattan Island, near the Jersey shore opposite Manhattan, and the bottom near the Long Island shore in the East river, were polluted almost everywhere, at least to the pierhead line.

Midstream in the Hudson and East rivers the bottom was fairly free from deposits of sewage solids, and was generally so hard that the samples could be obtained only with difficulty. The Lower bay was polluted, particularly in the principal ship channels. Frequent foul deposits were found in the Kill van Kull and in the Newark bay, especially near Elizabethport and Newark. The deepest deposits were found at the pierhead line off Elizabethport, Port Richmond, Hoboken and at the mouth of Gowanus canal.

CHAPTER X

DIFFUSION AND DIGESTION OF SEWAGE IN NEW YORK HARBOR

SECTION I

Freedom from evil consequences attending the discharge of sewage and other wastes into New York harbor depends upon the bodily transportation of the refuse matters from the harbor to sea by means of tidal currents and the assimilation of the remainder by the water itself. It has been found that, owing to a backward and forward oscillation of the tidal currents the sewage is not carried promptly to sea, and it is evident that the ultimate disposal of the impurities must depend largely upon the phenomenon of assimilation.

COMPOSITION OF THE POLLUTING WASTES

The term sewage is used in this chapter to mean the wastes which flow from dwelling houses, factories and streets through the municipal drainage systems of New York and neighboring municipalities.

In a general way, sewage may be considered to contain about 998 parts of water and two parts of foreign matter; the last being about equally divided between animal and vegetable refuse. Sewage contains, beside human feces, numberless solid and liquid wastes of human and animal origin. Among the visible ingredients are garbage, matches, corks, bits of paper and cloth, and particles of human excrement.

Quantity of Fecal Matter Produced. The quantity of solid excrement produced by an average human adult has been taken by Roechling ("Passage of Excreta Through House Drains," *Journal of the Royal Sanitary Institute*, July, 1909, p. 216) to be one-quarter of a pound for each discharge. The specific gravity of feces this author takes at 1.067, and from this he estimates that the bulk of a human discharge is about 0.0234 imperial gallons. This is diluted with from 100 gallons to 200 gallons

of water. Estimating the present population of New York at 4,500,000 people there is discharged every day about 560 tons of fecal matter. To transport this material away by rail would require a trainload of about 28 ordinary freight cars.

Sewage is never constant in quality or quantity. The sewage from a residence section differs from that from a manufacturing district. The sewage produced in any locality varies both in quality and quantity at different hours of the day, different seasons of the year and with the weather. Being of such changing composition it is obviously impossible to give figures which will carry an exact idea of the chemical or physical properties of the sewage of New York and its neighboring municipalities. A sufficient knowledge of the composition of the sewage can be had from figures which have been compiled for other cities.

Composition of Sewage. Winslow & Phelps¹ consider that 800 parts per million of total solids is a liberal figure for American cities and is exceeded by few. These authors state that, of the total solids, it may be said roughly that from 60 per cent. to 70 per cent. are in solution either liquid or colloidal, the remainder being insoluble matter in suspension. As to the nature of the solids, about one-half is matter which can be driven off by ignition in the laboratory, and is consequently assumed to be chiefly organic matter. The remaining non-volatile residue is mineral matter.

About 50 per cent. of the organic solid matter in sewage is dissolved and the remainder is held in suspension. Of the mineral solids in sewage 75 per cent. are present in a dissolved state. In a sewage containing total solids to the extent of about 800 parts per million, Winslow and Phelps estimate that 500 parts per million of solids are in solution and 300 parts are in suspension. Of the organic solids, amounting to 400 parts per million, 200 parts are in solution and 200 parts in suspension.

Of the organic matters present, either in solid or liquid state, 150 parts per million are nitrogenous and 250 parts are not nitrogenous.

The total carbon amounts to 200 parts, the total nitrogen to 15 parts, and the fats, etc., to 50 parts per million. This sewage is supposed to represent the liquid wastes of a population which uses an average of 100 gallons of water per capita per 24 hours.

Composition of New York Sewage. The composition of New York's sewage is shown by Table I which has been made up by assuming New York's water consumption at 120 gallons per capita per day and prorating on this basis the various figures given by Winslow and Phelps above mentioned.

¹"Investigations of the Purification of Boston Sewage," United States Geological Survey Water Supply and Irrigation Paper No. 185, p. 13.

TABLE I
COMPOSITION OF NEW YORK SEWAGE
(Parts per Million)

Determination	Total	In solution	In suspension
Residue on evaporation.....	670	420	250
Mineral and ash.....	330	250	80
Organic and volatile.....	340	170	170
Nitrogenous.....	120	....	...
Non-nitrogenous.....	210	....	....
Fats, etc.....	42	....	....
Total carbon.....	170	....	....
Total nitrogen.....	12	....	....

Weight and Bulk of Sewage Solids. It is not necessary that the composition of the sewage which is discharged into New York harbor should be accurately known in order to form a conception of the burden of pollution which is put upon these waters. The aggregate quantity of the impurities constitutes the chief matter of interest.

The quantity of sewage impurities can be estimated in several ways. According to figures brought together by George W. Fuller, before the International Engineering Congress held at St. Louis, 1905, Trans. Am. Soc. C. E., Vol. LIX, p. 166, the average result of analyses of the sewage of ten cities for which figures are available indicates that the impurities are equivalent to 42.3 tons of dry solid material per year for every 1,000 inhabitants. Winslow and Phelps's figures prorated for New York conditions of 120 gallons per capita per day and reduced to Mr. Fuller's basis represent 46 tons of dry solid material per year per 1,000 inhabitants.

The 1905 population in the metropolitan district was found by census to be 4,128,396 for New York and 1,203,387 for New Jersey. According to the estimates of this Commission the total number in 1910 is 6,150,000. Assuming 90 per cent. of the population is connected with the sewers, the total number of persons whose sewage enters the harbor or its tributaries is 5,540,000. The aggregate quantity of sewage material discharged per year is equivalent to 255,000 tons. About one-half of this is capable of putrefaction or already advanced to some extent toward that condition.

One ton of dry suspended matter is equivalent to about 50 tons or about 55 cubic yards of wet sludge. On this basis the population of the metropolitan district empties

into the harbor each year the equivalent of 12,800,000 tons of sludge, having a bulk of 14,000,000 cubic yards. The area of the various tidal waters in the vicinity of New York above the Narrows is about 50 square miles. The sludge formed each year if spread out over this area would cause a deposit of about three and one-half inches.

The suspended matters in sewage consist of bits of feces, toilet paper, newspaper, coagulated soap, street wastes, kitchen refuse, floor sweepings, etc.

Feces, as ordinarily discharged contain about 35 grams, or .077 pound, per person per day of matter which will remain suspended in sewage. This amounts to 14 tons per 1,000 persons per year.

Toilet and newspaper entering the sewers may be estimated at 8 tons per 1,000 inhabitants per year.

Each person may be assumed to use .01 pound of soap per day and in doing so to remove at least four times this amount of suspended matter with grease and other material. On this basis about 11 tons of suspended matter are produced per 1,000 persons per year and emptied into the sewers.

The street wastes which enter the sewers, consist of organic and inorganic dirt derived largely from feces and urine and an almost infinite number of comminuted solid matters. Table II shows the amounts of these matters which may be estimated to enter the waters of New York harbor through the sewers.

TABLE II

ESTIMATES OF THE QUANTITIES OF STREET WASTES WHICH ENTER NEW YORK HARBOR
ANNUALLY FROM THE METROPOLITAN DISTRICT

Material	Tons
Inorganic street dirt.....	18,300
Organic street dirt.....	26,200
Total.....	44,500

Prorating the above amount of street dirt among the 5,540,000 inhabitants in the metropolitan district assumed to be connected with the sewers, there are obtained 8.3 tons per 1,000 persons annually. Table III summarizes these figures.

TABLE III
SUSPENDED SOLIDS IN SEWAGE

Material	Tons Per 1,000 Inhabitants Annually	Tons Entering New York Harbor Annually
Feces.....	14	77,600
Toilet paper and newspaper.....	8	44,300
Soap and washings.....	11	60,900
Street wastes.....	8	44,300
Miscellaneous.....	4	22,200
Total.....	45	249,300

Appearance of Sewage. When a sample of sewage is taken from a New York sewer and put into a clear bottle, the sewage has a dirty gray color, with an unpleasant, rather musty odor. It contains small pieces of newspaper and toilet paper and finer particles of suspended matter ranging in size much as do the grains of ordinary building sand. Most of the particles will pass through a screen having a mesh of one-eighth of an inch, the largest particles at the surface being excluded. The small solid particles are composed of fecal matter and paper broken up by friction within the walls of the sewers and small pieces of fibre, cloth, a few glumes and mineral detritus.

Upon standing, many of the particles settle out, causing a dirty, grayish, slimy sludge to accumulate upon the bottom of the bottle. After all the particles have settled out, the liquid which remains in the bottle looks like water which has been used for washing where a good deal of soap has been employed. If allowed to stand for a few hours at ordinary summer temperature, the sewage becomes putrid.

If greatly diluted or put upon a sufficient area of land sewage does not putrify nor give off offensive odors. In either case the decomposable organic substances are gradually converted into harmless and inoffensive compounds. The offensive odors of putrefaction are produced only when the natural purifying agencies are overtaxed. All methods of purifying sewage aim to resolve the substances which are capable of putrefaction into such shape that they may be dealt with separately, under conditions which are within control.

It is popularly supposed that the presence of human excrement forms a prominent ingredient of sewage, but this is not the case. It is a subject of frequent remark among visitors to sewage disposal works that comparatively little human excrement is visible. The reason for this is that particles of solid excrement large enough to be

easily distinguished are broken up in passing through the plumbing of the houses and the sewers and diluted to such an extent that they are no longer recognizable.

The Bacteria in Sewage. Sewage contains large numbers of bacteria. One of the principal sources of these germs is the excreta of human origin which the sewage contains. Saprophytic germs, that is micro-organisms concerned in the decomposition of organic wastes, are also very numerous. The number found in one cubic centimetre of sewage averages from a few hundred thousand to many millions.

As pointed out by Friedenwald & Leitz,¹ the germs contained in the human intestine are of comparatively few species. Strasburger² found that the total numbers of bacteria produced by a normal person on an average diet was one thousand million per day. One-third of the dry substance of feces is bacteria. On this basis the number of bacteria produced each day by the inhabitants of the metropolitan district would be about six thousand million million.

SECTION II

THE SOLIDS OF SEWAGE

The solid matters which are carried by the sewage may be divided into three classes: First, the solids which sink soon after the sewage is discharged into the harbor; Second, those which continue to float for some time on the surface of the water; and, Third, those which are long carried in suspension in the body of the tidal streams.

It is evident that particles do not always remain in one or another of these divisions. Many which at first float gradually become broken up or watersoaked and sink beneath the surface of the water, and thus pass from the second to the first division or to the third.

In the third class are the colloids and finely divided particles of suspended matters. The colloids may be precipitated by sea water. When allowed to settle from sewage the precipitated colloids and solid matters form sludge or, as usually termed in the investigations of the Metropolitan Sewerage Commission, black mud.

Accumulations of sewage deposits are exceedingly difficult to handle except by pumping. When raised in the bucket of a dredging machine much of it flows back into the water from which it was taken. The United States Government in dredging Ambrose channel, now the principal entrance to New York harbor from the sea, made

¹ "Bacterial Content of Feces," *American Journal of the Medical Sciences*, November, 1909, p. 653.

² *Zelt. f. Klin. Med.*, 1902, Band XLIV, S. 413.



The Commission's Floating Laboratory Equipped with Casks of Dyed Sewage Used in Experiments on Diffusion. The sewage, dyed green or red, was usually discharged at a predetermined depth below the surface and the circumstances attending its subsequent appearance were noted

use of suction dredges and pumped large quantities of sludge which had accumulated there, into seagoing vessels which transported the black and often offensive mud to the open ocean.

THE SOLIDS WHICH SINK

The sewage particles which sink as soon as the sewage is discharged into the harbor water find a lodgment on the bottom which is permanent or temporary according to a number of circumstances. Among these circumstances the weight of the particles, the velocity of the tidal current into which they are discharged and the smoothness or roughness of the bottom are the most important factors.

Extent of Bottom Pollution. Analyses which the Metropolitan Commission has made of New York harbor have shown that deposits of sewage solids exist not only in the immediate neighborhood of sewer outfalls but at considerable distances from the sources of contamination in New York harbor. The bottom of the inner harbor is, for the most part, covered with a slimy, black, offensive mixture of detritus in which sewage solids are a prominent ingredient.

The only parts of the harbor which are not contaminated by sewage sludge are those where the tidal currents are too swift to permit deposits of any sort to form. Most of the bottom of the Lower bay, the upper Hudson and the Long Island Sound approaches to New York are covered with sand, silt and unpolluted mud; the investigations upon which these statements are made have been extensive. Over 1,500 samples have been collected from the bottom and carefully analyzed to determine the extent of the pollution of the harbor bottom by sewage. The bottom has been penetrated to a depth of ten feet and samples have been collected which showed that sewage solids had been deposited to at least that depth. It is not too much to say that wherever tidal conditions permit sediment of any kind to accumulate pollution with solid sewage particles takes place.

In some places extensive banks of black sludge containing sewage refuse occur. So far as known these banks have not yet seriously impaired the use of the main harbor channels for navigation, although it seems probable that if a careful estimate of the nature and quantities of material dredged every year could be made it would show that an appreciable amount of expense is chargeable to sewage sludge.

The dredging which is done to keep open the slips, ships' basins, canals and creeks in the metropolitan district is partly attributable to sewage deposits. The cost of removing this material is large. About 350,000 cubic yards are yearly dredged from the water of Manhattan Island by the Dock Department of The City of New York alone. A part of the material removed from the Ambrose channel in the Lower bay during the

construction of that entrance from the sea consisted of sewage sludge. Considerable doubt existed at one time concerning the origin of this material, but investigation has led to the opinion that the material was of sewage origin and that it was carried to its place of deposit by the waters from the Upper bay.

Power of a Current to Move Sewage Particles. A slight current has sufficient force to move the light sewage particles which settle upon the bottom. This is well illustrated by the fact that deposits do not take place in the main tidal channels of the large rivers nor upon a large part of the flats in Upper New York bay although suspended matters are undoubtedly present in the water. The currents over the flats attain a velocity of about one foot per second at ordinary tides and this apparently is sufficient to keep them free of sewage debris.

As is well known, the capacity of water to move solid matter from a condition of rest on the bottom of a stream varies with the sixth power of the velocity of the stream. If the velocity is doubled the increase in the force which is capable of moving a particle from a condition of rest on the bottom is multiplied 64 times. This power of a stream to move or roll solid matters along the bottom accounts, in part for the formation of sand bars at the mouths of rivers, as well as for the movement of gravel and other heavy solids along the beds of streams. The solid material carried by sewage which accumulates near the mouths of sewers and forms sludge banks where the currents are weak is continually being moved from place to place by stronger currents sufficient to set in motion solid sewage particles. It is equally clear that the currents are capable of keeping in motion many of the particles which are so moved.

Disintegrating Effect of Water on Sewage Solids. In addition to the mechanical effect of currents other forces are at work which prevent the accumulation of larger deposits than now take place in the immediate vicinity of sewer outfalls.

Among the substances which subside are masses of solid, organic particles which are broken up by the mere lubricating or dissolving power of the water. A slight movement is sufficient when applied at the right place and moment to separate the loosely bound aggregates of sewage solids into their constituent parts.

Hydrolysis of Sewage Solids. Once solid matters have accumulated upon the bottom to a depth of a few inches, changes in their constitution take place through the action of bacteria. The essential action here is the breaking down of solids to form liquids. This action proceeds rapidly beneath the surface of the bottom. It takes place chiefly in the absence of oxygen. It is due in part to bacterial activity and in part to the action of enzymes.

The liquefaction of solids in the absence of oxygen is a phenomenon of putrefaction and is attended by the production of offensive-smelling gases. The gases take the shape of bubbles and rise to the surface. In so doing the bubbles break open the accumulations of solid matter and carry black masses of deposits to the surface. Bubbling is a constant phenomenon between the slips of Manhattan Island. So active is it in places that the water sometimes takes on the appearance of effervescence, with a sound like rain falling upon the water.

Actively assisting in the mechanical disintegration of sewage sludge at the bottom of the harbor are a multitude of minute animals and plants including the infusoria. These propagate in vast numbers in the sludge and by their activities tear apart and render still more minute particles of solid matter which contain enough organic material to serve them as food. Some of these organisms require a considerable supply of oxygen and live at the surface of the deposits while others are able to exist with a very small supply of it and do their work beneath the surface.

Odors from Deposits. The odors caused by the putrefaction of deposits upon the bottom of New York harbor are the most intense and offensive of any odors produced by the discharge of sewage into the harbor. These odors are capable of imparting a peculiar offensiveness to the water. Offensive, also, and more prevalent, is a peculiar greasy, nauseating odor. This greasy odor is noticeable along the whole shore line of the inner harbor, particularly near beaches.

The odor of fresh sewage is generally musty and not unlike that sometimes noted in damp cellars and other enclosed places which are in need of proper ventilation. This musty odor is doubtless produced by molds, enormous growths of which have been found by the Metropolitan Sewerage Commission in some of the sewers of Manhattan. Sewage air is usually warm and saturated with moisture, for which reason the odors present are especially apparent. The odor of sewage should be familiar to the people of New York for the sewers are ventilated through manholes and catch basins in the streets and some of these streets are daily crowded from curb to curb with people. Many large buildings discharge spent steam into the sewers with the result that clouds of vapor possessing the nauseating odor of cooking sewage are discharged into the streets.

Where for any reason the sewage is not promptly discharged from the sewers but stands either in contact with harbor waters, as in the case of tide-locked outfalls, or because the sewers have not proper grades to cause the sewage matters to run out promptly, pronounced and offensive odors of putrefaction are often given off. If a sewer is of moderate length, as are most of those in the metropolitan district of New York, and of proper grade, the sewage does not become putrid in the sewer for it is dis-

charged too soon after it is produced to enable the fermentative changes involved in putrefaction to advance far. Substances exist in the sewage which are capable of putrefaction and are actually offensive, but the offensive properties of these substances are not transmitted to the whole mass of sewage unless the latter becomes stagnant. In fact they are diluted and rendered less obnoxious for the time being. It is after the sewage solids have been deposited upon the harbor bottom and decomposition has set in that the putrefactive changes become most pronounced and the most offensive odors are given off. The quiet arms of the harbor, such as the creeks and spaces between the long piers, most of which are veritable sewage traps, are the principal places where offensive odors are produced.

THE SOLIDS WHICH FLOAT

Referring now to the second class of solid sewage particles, we will consider the matters which float upon the surface. These impurities are objectionable because they add to the total organic content of the water and on account of their appearance.

During calm weather fields of grease, floating sewage matters and wood may be seen in New York harbor. These fields are often many acres in extent and sometimes a mile or more long. They preserve their integrity with remarkable persistence and are not easily broken up by ordinary winds or waves or the movements of passing vessels. There is usually little difficulty in detecting solid human excrement in these floating masses.

Composition of the Floating Matters. The floating particles of sewage are not necessarily composed solely of matters which are lighter than water. Sewage solids are often made up of aggregates, most of whose ingredients are heavier than water but which contain enough gas to keep them at the surface.

There is a more or less constant deposit of solid matter from sewage particles at the surface, some of the disintegrating particles joining the mass of material which flows in the body of the current and some descending to the bottom. The ceaseless mechanical action of the waves, the attrition which the floating particles experience in contact with other floating solids, the impact of the water against piers and other obstructions and the destructive effects produced by vessels, all help to disintegrate the solids and resolve them into smaller masses. The effect of these forces is plainly discernible in New York harbor. While large pieces of excrement are nearly everywhere observable, by far the greatest number of solid matters are of comparatively small size.

Although solid matters are broken up into smaller particles by mechanical action, actual liquefaction of solid matters does not take place so much at the surface, as at

the bottom of the water. Fermentative action occurs only in the deposits which settle at the bottom and in water whose oxygen is entirely exhausted.

The water within a few feet of the surface is usually more heavily charged with bacteria and offensive matter than the water at greater depths. This, apparently, is due to the fact that polluting matter enters near the surface and to some extent remains there.

Appearance of the Discharging Sewage. Where a sewer discharges into the harbor a marked discoloration of the water usually occurs. The water contains a great number of visible particles of paper, feces, and other solid matters. The size of these particles varies from scarcely distinguishable objects up to solid masses six inches or more in length and several inches in diameter. The water, which is generally of an olive, slightly turbid appearance, becomes a brownish gray and decidedly turbid. The surface which is discolored is sharply separated from the surrounding water. As the current of harbor water carries the sewage away from the outfall, this discolored area expands. To all appearances it keeps its integrity well but it eventually loses its characteristically turbid hue by intermixture with the water beneath.

Some mixture between the sewage and harbor water takes place from the outside edges of the discolored area, but diffusion proceeds chiefly, apparently, from the bottom of the mass of sewage. The surface of the discolored area is covered with a film of grease. This greasy film is persistent; it lasts much longer than the discolored area with which it is at first associated. Eventually the grease becomes broken up by the waves and eddies, but it remains upon the surface in detached films varying from a few square inches to many acres in extent.

Beneath the surface of the water long after the brownish turbidity has disappeared are small particles of paper and great numbers of minute white flakes. These flakes consist largely of insoluble soaps which have been produced by the chemical combination of soluble soaps from the sewage with the calcium and magnesium salts of the sea water.

Transporting Power of the Currents. Sewage particles which float upon the surface are carried from point to point by the tidal currents and by the action of wind. The currents cause a dispersion of the floating solids to a certain extent, but it is remarkable how long a mass of sewage matters may remain intact upon the surface. The solids may be carried several miles without losing their characteristics. Some remains of fruits and vegetables, as well as well as matches, cigar ends, and other large light solid matters from the sewage float on the surface indefinitely.

Large quantities of driftwood come to the shores, carried there apparently by the action of the tidal currents and by the wind. Much driftwood is collected

by poor persons and used for fuel. There are places on the shores of New York harbor where this supply of fuel is practically inexhaustible.

On the south shore of Staten Island and on the west end of Coney Island the driftwood is collected into piles and burned at the water's edge in order to get rid of it. There is often a peculiarly disagreeable greasy odor to these accumulations.

Effect of Winds. The wind, which exercises an important influence upon the rise and fall of tide in New York harbor has a decided effect upon the movement of floating objects.

A strong westerly wind causes floating matters to flow to and along the easterly shores, and conversely, when the wind blows from the east a concentration of floating sewage matters is cast upon the western shores of the harbor. A moment's reflection will show that the solid matters which are cast ashore or brought near it by the wind are likely to remain there owing to the fact that they become sheltered from all winds except those which are capable of forcing the floating matters nearer to the land.

The effect of wind upon floating objects is twofold:

First, The wind exercises a direct propelling effect upon objects which lie in part above the surrounding water, as a ship is moved under sail;

Second, The wind causes a general movement of the whole surface of the water, which, in turn, carries floating solid matters along with it. This second effect is as pronounced as the first.

Movement of Solid Particles Toward the Shore. It has frequently been noted in the studies of the movement of floats set adrift by the Metropolitan Commission that floating solid matters sometimes go ashore. The cause of this shoreward movement was at first thought to be due to wind. This was found to be an insufficient explanation to account for all the strandings and it was then for a time believed to be caused by the movements of vessels. Vessels, it will be noted, cause a movement of water toward shore both when they approach and when they leave a dock. Later it was observed that the floats went ashore on flood more often than on ebb currents, and from this it has gradually come to be suspected that, aside from the winds, a principle of general application is at work to strand the floats. It is probably by virtue of this principle that the movement of floating matters shoreward is observable in all rivers which are subject to freshet. During rising stages logs and driftwood float to the shore, and during falling stages they move to the centre of the stream.

New York Harbor's Sewage Traps. When floating solids reach the shores of New York harbor the piers and shipping basins catch them and hold them as in a trap. These places, protected as they are from the direct force of the tidal currents, afford

excellent opportunities for sedimentation. They catch the solids which float into them through the action of wind, rising stages of tide and the action of vessels and remain there, for there is no counter action to any of these forces to carry the solids away.

The sewage traps of New York are of much interest when studied in connection with the diffusion and digestion of the sewage which is emptied into these waters. Knowledge of their behavior makes it easy to understand why it is that the slips continually require to be dredged in order that a proper depth of water may be preserved for navigation, why the dredged material is so foul and why it is that sewage solids accumulate between the piers even when the bottoms of the main tidal currents beyond the pierhead line are relatively free from deposits of sewage origin. Knowledge of their action makes it easier to understand why the extension of the sewer outfalls a little further out toward the center of the tidal currents produces only a partial improvement.

THE SUSPENDED SOLIDS

Nature of the Suspended Solids. The specific gravity of the solid sewage matters which flow through the body of the tidal currents is nearly that of the water itself. These particles in collected form make sludge, which is a mixture of solid and semi-solid debris. Even after long standing to remove the water, sludge contains from 60 to 90 per cent. water.

Effect of the Velocity of Current on Transporting Power. The transporting power of water for suspended sewage solids varies as the square of the velocity of the moving current. Therefore if the velocity is reduced by one-half the capacity of the water to carry solid particles in suspension will be reduced to one-quarter. If the stream is loaded to its carrying capacity three-quarters of its load will be deposited when the velocity is reduced by one-half.

Velocity of Flow in the Sewers in the New York District. The velocity of the currents into which the sewage of New York and neighboring municipalities is discharged is often less than the velocity which occurs in the sewers. When harbor water backs into them by reason of the rising tide their flow is retarded or stopped. The flow is often impeded by tidal water and deposits in the sewers take place. These deposits are eventually flushed out by the accelerated flow when the tide recedes, so that the final effect is that about the same amount of solid matter is discharged as would be discharged if an average rate of flow was maintained. The velocity necessary in order for sewers to be self-cleansing is usually taken to be two to three feet per second, and this may be assumed to be the average velocity which is maintained in the sewers of the metropolitan district.

The velocity of the water into which the sewage is discharged varies considerably according to the location of the outlet and the stage of the tide. The velocity in the main tidal currents is also different in different parts of the harbor. Sometimes the sewers discharge well out from shore, but for the most part the points where they empty are not in the main currents. It is safe to say that the full force of the tidal currents never occurs at a sewer outfall. It not infrequently happens that there is a complete absence of current where the sewers discharge.

Velocity of Tidal Currents. The extensive studies of tidal phenomena in New York harbor made by the United States Coast and Geodetic Survey and by the Metropolitan Sewerage Commission have given results from which the following data have been derived:

There is a point in the tidal period when the velocity of the current is at a maximum, or strongest. The maximum, minimum and average velocities given in Table IV refer to this strongest current.

TABLE IV
VELOCITIES OF STRONGEST CURRENT IN FEET PER SECOND

Channel	Maximum	Minimum	Average
Hudson.....	7.9	2.0	4.1
East.....	7.8	2.7	5.0
Harlem.....	3.9	1.2	2.4
Narrows.....	4.7	1.5	3.0

The least strong velocities occur in the Harlem river and the greatest in the East river. The velocities in the Narrows exceed those in the Harlem river but little, while those in the Hudson and East rivers are, roughly, twice as great.

The velocities of the currents in the more open parts of the harbor are much less than in the more restricted localities where the cross sections are smaller. The velocities in the Upper and Lower bays are variable, depending on the location. Over the extensive flats in the western part of Upper New York bay the currents seldom exceed 1.5 feet per second in velocity.

To fully grasp the meaning of these figures it should be understood that the velocities given represent the movement of water at the time the tide is producing its greatest effect.

Changes in Velocity of Currents. Inasmuch as the currents stop and reverse four times a day it is evident that the figures show more the currents which are available for moving for short periods of time particles which have settled upon the bottom rather than currents which are capable of preventing deposits. Such high velocities exist for but brief periods. During most of the time the conditions are more favorable for the deposition of sewage solids than during those brief periods.

The figures given for the velocities of currents must also be understood to represent surface conditions. The velocities at the bottom of the tidal currents are less than those stated.

The mean velocities are approximately four-fifths of the surface velocities and the bottom velocities still lower. So that the lower down a particle has fallen the less chance it has of being again picked up and carried along, unless it has come to a condition of actual rest.

The Commission's studies show that much more deposition may be expected to take place in the Harlem river than elsewhere. Table V shows the percentage of time during which deposition may be expected to take place at the points noted.

TABLE V
PERIOD OF TIME DURING WHICH SEWAGE SOLIDS MAY BE DEPOSITED

Place	Per cent. of time velocity is less than 2 feet per second in		
	Flood Currents	Ebb Currents	Total Cycle of Tide
Narrows.....	59	40	50
Hudson river.....	39	25	32
East river.....	29	25	27
Harlem river.....	70	72	71

Currents Necessary to Move Solids. The current necessary to move solid particles along the bottom is very slight. Table VI gives the required velocities to move various kinds of materials.

TABLE VI
VELOCITIES REQUIRED TO MOVE SOLID PARTICLES

Kind of Material	Velocity required to move on bottom	
	Inches per second	Miles per hour
Fine clay and silt.....	3	about $\frac{1}{8}$
Fine Sand.....	6	about $\frac{1}{4}$
Pebbles half-inch in diameter.....	12	about $\frac{1}{2}$
Pebbles one inch in diameter.....	24	about $1\frac{1}{2}$

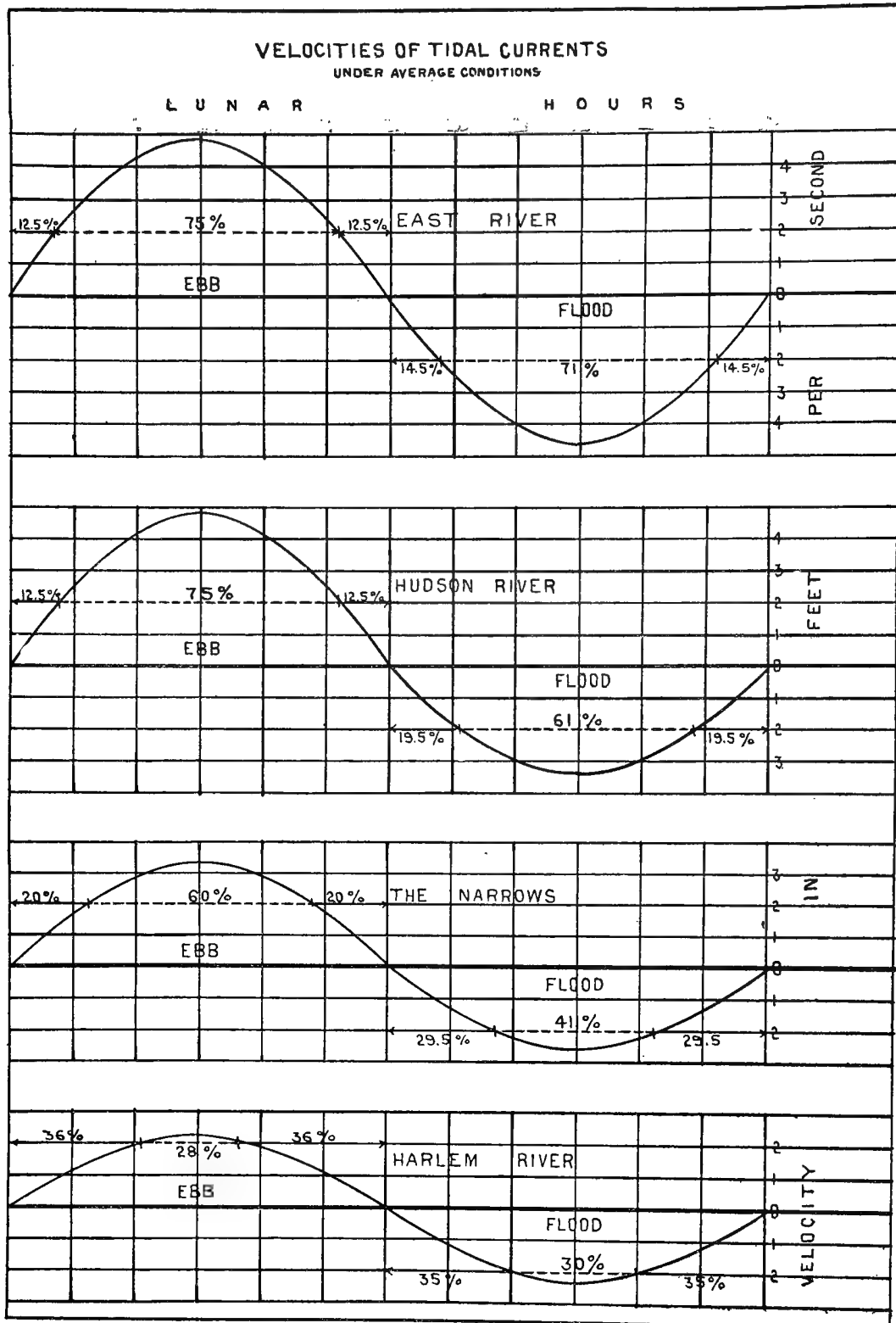
It is well to remember that these figures relate to the movement of solid matters along the bottom and especially to the initiation of movement. The power of streams to lift and transport solid particles in suspension is not nearly so great.

Lack of Uniformity in Currents. It may at first appear that solid particles should settle as rapidly in a uniformly moving stream as in a quiet body of water. The fact is, however, that large streams of water do not move uniformly throughout their depth and breadth; there are always some eddies which have an upward motion sufficient to counteract the downward movement of the particles. This upward force of the eddies together with the downward movement of the solids accounts for the fact that the relative position of the solid particles is continually changing.

The upward movements of currents are greatest in shallow streams and where the onward velocity is great, but it exists to some extent in all streams. Conditions which affect it are the shape and size of the channel through which the stream is moving, impediments of various kinds which the water encounters and lack of uniformity in the velocity.

Irregularities in the bottom do not occur to a conspicuous extent in the harbor of New York, but the movements of vessels and the obstructions offered by piers on the waterfront must be taken into account. The chief effect of these influences appears to be restricted to the currents which flow along the shores and to the upper part of the waters.

It has been well established by the investigations of the Metropolitan Commission, that a lively and complete inter-mixture of water does not occur in the harbor



of New York. The water is of different quality at different depths below the surface and of different composition at different distances from shore. At most places there is usually a larger proportion of sea water at the bottom than at the surface, more intense pollution near land than in midstream, and more intense pollution at the top than in the waters below.

That tidal harbors are often lacking in vertical circulation is well known. The phenomenon of the underrun, which is a current of sea water flowing inland close to the bottom of a channel, affords an illustration of this point. The outflow of land water on the surface of rivers where they join the sea is another example of the same phenomenon.

Relative Capacity of Land Water and Sea Water to Transport Sewage Particles. It is a fact of great importance, but one generally overlooked, that the transporting power of a river for solid particles in suspension is diminished by the presence of sea water. Water which is strongly saline will not transport as much solid matter in suspension as will water which is without salt. This means that rivers which discharge into the sea deposit solid matters not alone because the velocity of their current is checked by the waters of the ocean but because they become more salty.

Sewage which is discharged into a tidal harbor will deposit more solids than would be deposited if the discharge took place into a land water stream flowing at the same velocity. The capacity of a harbor for carrying sewage matters to sea, therefore, cannot be estimated safely from information obtained merely from a study of inland rivers.

Experiments to Show Relative Rate of Deposit of Solid Matters in Sea Water and Land Water. In order to compare the relative rate at which sewage sludge deposits in land and sea water the Metropolitan Sewerage Commission made a number of experiments, the result of which was to show that deposits took place much more rapidly in sea water than in land water.

Two bottles, alike in all respects, were nearly filled, with sea water in one case and land water in the other. An equal quantity of sludge which had been deposited from sewage was then added to the water in each bottle. The bottles were thoroughly shaken and set upon a table to enable the deposit to settle out.

At the end of one-half hour the water in the bottle containing sea water was noticeably clearer than the water in the other. At the end of one hour the difference was very marked. A heavy deposit had settled upon the bottom of the bottle containing sea water and the supernatant water was clearing rapidly. There was little change in the bottle containing land water. At the end of two hours there was little differ-

ence in the appearance of the land water. Most of the sludge had settled upon the bottom of the bottle containing sea water and the water was clearer than it had been.

At the end of three hours some deposit was visible at the bottom of the land water, but the water itself was not as clear as the sea water had been at the end of the first half hour. The bottle containing sea water had deposited practically all the sludge which had been put into it. As nearly as could be estimated from mere inspection the sea water had deposited its suspended matter more than twelve times as rapidly as had the land water.

Distribution of Hard and Soft Materials. The material at the surface of the bottom of New York harbor varies considerably in composition at different places. Taking a standard United States Government chart of the harbor as a basis, areas described as "soft," "sticky," "mud" and "ooze" were outlined and colored by the Metropolitan Sewerage Commission. These colored areas showed interesting results. Above the Narrows the hard areas were found to be all situated well out toward the centre of the waterways, and the softer areas near the shores. Below the Narrows this order was reversed.

Condition of Channels, Now and Formerly. Interesting comparisons were made by the Metropolitan Sewerage Commission between the most recent charts issued by the Government and the earliest charts, with a view to determine the extent to which the harbor has been filling with sewage sludge.

One of the earliest charts for which any precision can be claimed is the well-known work which was published in 1780 by J. F. W. Des Barres, from surveys and observations made by officers of the British navy. This chart was less accurately made than the charts of the present day, but it is correct enough to show that the most important channels and shallows which exist at the present time existed one hundred and twenty-three years ago. In Upper New York bay what is now called the east anchorage was termed "Mud Flatt," while the shallows on the Jersey shore opposite were known as "West Flatt." The main channel to sea was, as nearly as can be seen, in about the location of the main channel to-day. The depths in the channels have increased rather than diminished; a result which has been accomplished by dredging.

The earliest chart of New York bay and harbor which was issued by the United States Government was made under the direction of Thomas R. Gedney, Lieutenant, U. S. N., and published in 1844-5. This chart, like its predecessor just mentioned, seems to confirm the belief that the channels and shallow parts of the harbor have not suffered serious impairment in recent times.

This is somewhat surprising in view of the quantity of sewage entering these waters and the fact that the amount of sediment due to natural causes carried by the rivers of the metropolitan district into New York harbor each year is very great, not to mention the drift of sand toward the mouth of the harbor along the Long Island and New Jersey beaches.

Normal Solid Matter Carried by the Hudson. As compared with streams which empty into the Atlantic south of New York the Hudson and other rivers which discharge in the metropolitan district carry but little solid matter derived by natural agencies from the land. The Hudson for 60 miles above New York has but few tributaries. The westward slope of the Catskills carries much natural drainage away from the Hudson. The main body of water collected by the Hudson river is from mountain sources. The principal tributary which flows through fertile land is the Mohawk, which empties into the Hudson 150 miles from New York. From this point to the ocean the Hudson may be considered to be a tidal basin in which opportunities for sedimentation everywhere occur.

The amount and composition of the suspended matter derived from natural sources probably varies considerably at different seasons of year, according to the amount of rainfall and similar conditions. In considering the question of river sediment, it must be remembered that a large portion of the material which is carried by the river is not transported as matter actually in suspension, but is pushed and rolled along the bottom. This bottom drift, as it is termed, may be an important element in the total amount of material moved. There are, apparently, no reliable observations of the amount of this material carried by any river except the Mississippi, and in this case the observations are not as exact as could be desired.

SECTION III

THE LIQUIDS OF SEWAGE

Reference has been made to the action of bacteria and minute animals in breaking up the solid particles of sewage and liquefying them. The liquid so produced, as well as the liquid natural to the sewage, passes through certain chemical changes while undergoing assimilation. Nature requires that all organic matters be resolved into stable mineral forms. In this final shape matters of sewage origin are quite inoffensive and incapable of becoming so. The sewage solids must be liquefied before they can be oxidized.

OIL AND GREASE

Sewage contains nothing which is more characteristic or which alters more slowly in composition when discharged into harbor waters than oil and grease. The quantities

of the greasy matters are not large, but the effects which they produce are unmistakable. Mention has been made elsewhere of the greasy sleek which sewage produces upon the surface of the water into which it is discharged. This sleek is not conspicuous in New York harbor, but at times large patches of it are distinctly visible.

This sleek floats upon the shores and imparts a strong, unpleasant greasy smell. The driftwood smells of it. Balls of grease formed in the sewers of New York have been found on the sea beaches of New York and New Jersey many miles from the city.

Grease of Industrial Origin. There are many industries situated on the shores of New York harbor which produce oil and grease and discharge it as waste into these waters. Of these oil refineries are the most prominent.

It is probable that oil tank vessels entering the harbor in ballast sometimes pump their greasy water overboard before taking on a new load of oil. Manufacturing establishments, slaughter houses and, in fact, most factories, refineries, gas houses and industrial establishments empty their liquid wastes into these waters.

Grease from Dwellings. The aggregate quantity of grease wasted from private dwellings, hotels and restaurants is large, although figures are not available to show the exact amount. Grease enters the sewers in most concentrated condition when poured in liquid and semi-liquid form from cooking utensils through kitchen sinks, but a continuous stream of greasy matter is contributed in the soapy water which is an invariable and prominent constituent of sewage.

THE LIQUID ORGANIC MATTERS OF SEWAGE

We have seen that 50 per cent. of the organic matter of sewage is present in liquid form. Besides the amount of liquid organic matter which the sewage carries, it is to be noted that all solid organic matters must assume the liquid form before they can be assimilated. The whole process of assimilation then becomes essentially one of oxidation.

The Phenomena of Oxidation. The oxidation of sewage takes place in several ways:

First, a small amount of direct oxidation of certain liquid chemicals in the sewage occurs. The oxygen for this reaction is that contained in all natural water which is the liquid carrier portion of the sewage.

Second, bacterial action may oxidize directly another portion of the liquid organic matter and abstract more of the dissolved oxygen. If sufficient oxygen is present, the process takes place without producing foul odors.

Third, liquid and solid organic matters broken down by putrefactive action produce unstable compounds which must later become oxidized by fermentation. If there is an insufficient amount of dissolved oxygen present it will be abstracted from compounds containing oxygen.

The oxidation of organic matters is essentially a process of combustion. Oxygen is required and carbon dioxide is produced, as are ammonia and water. Finally the ammonia is oxidized to nitrous and nitric acids, and these, uniting with alkaline substances natural to the water, form nitrates.

Source of Oxygen. The oxygen which is available for the oxidation of the impurities is that which is dissolved in the water and in dissolved chemical compounds containing oxygen. The principal source of the dissolved oxygen is the atmospheric air with which the water is in contact.

The depletion and replenishment of the amount of oxygen available for oxidation purposes is taking place continually. The original water or carrier portion of the sewage is originally saturated with oxygen. As the sewage flows towards its discharging point the dilution may be so small and the time so long that a large part of the original oxygen may have been consumed.

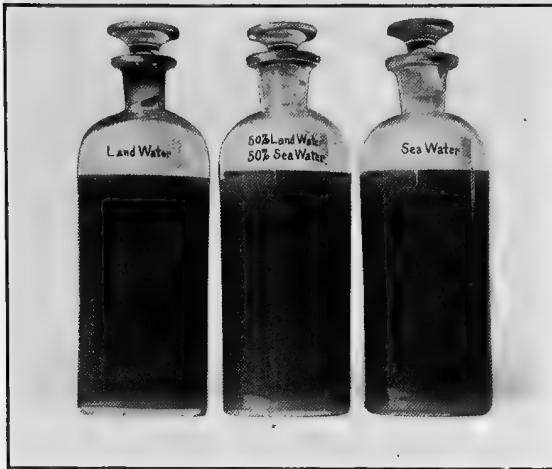
The discharge into the harbor of a sewage deficient in oxygen dilutes, so to speak, the dissolved oxygen of the receiving water. This operates to deplete the amount of oxygen per unit available.

The demand for oxygen of those products of putrefactive decomposition which are formed in the sludge at the bottom of the harbor causes a further depletion of the dissolved oxygen.

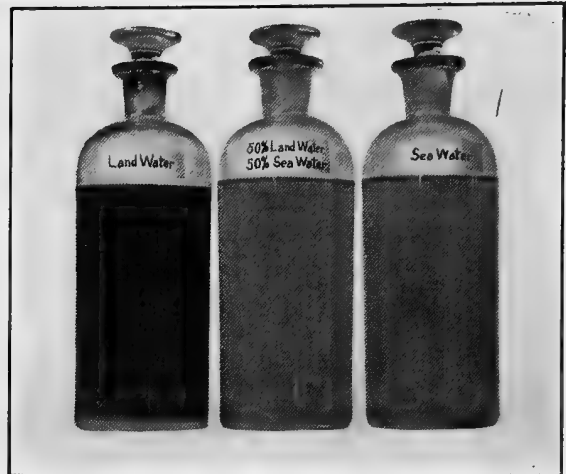
Rate of Oxidation Largely Dependent on Living Organisms. The chemical changes, and particularly the absorption of oxygen, which occur during digestion of sewage by water has been investigated in England by Letts and Adeney and made the subject of an exhaustive report to the Royal Commission on Sewage Disposal of Great Britain.¹ The work of these investigators was based on the well-known researches of Frankland, which showed that the essential cause of change was one of oxidation, and that of Dupré, who proved that the rate of oxidation was greater in the presence of bacteria than in their absence.

It appears from the opinions reached by Letts and Adeney that the significance of the presence of sewage matters in water depends not alone on the exact quantity and chemical composition of those wastes, but rather upon the fermentative properties of the mixture of water and sewage. The rate at which sewage matters undergo change depends largely upon the influence of the organisms present. Letts and Adeney were convinced that the purification of sewage in sea water was chiefly a physiological process analogous to the respiratory process of higher vegetable organisms, and they recognized that enzymic action is intimately associated with the process.

¹See Appendix No. 6, Fifth Report of the Royal Commission on Sewage Disposal, 1908.



Sewage Sludge and Water Immediately after Mixing



Sewage Sludge and Water two Hours after Mixing

Experiment Showing that Sewage Sludge Settles more Rapidly in Sea Water than in Land Water. After two hours the mixture of sludge with sea water showed a black deposit on the bottom and a comparatively clear supernatant fluid. The appearance of the land water with which an equal quantity of sludge had been mixed was practically unchanged



Dredging Sewage Sludge from between Docks in Manhattan. Dredges are constantly needed to remove black, foul-smelling deposits from the slips along the waterfront

The Two Stages of Decomposition. There are two stages of decomposition when sewage is discharged into water, according to Letts and Adeney.

In the first the organic matters are first fermented completely. The products of this fermentative change are carbonic acid and ammonia and organic substances possessing the chemical and physical properties of the humus of cultivated soils.

In the second stage of decomposition the humus matters and the ammonia compounds are further fermented, the resulting products being carbonic acid, nitrous and nitric acids and water.

The central feature of the first stage is the oxidation of organic carbon to carbon dioxide and the central feature of the second stage is the oxidation of the ammoniacal nitrogen to nitrous and nitric acids.

Since the self-purification of sewage polluted harbor water is so largely a matter of oxidation it is desirable to consider the extent to which the dissolved oxygen can be exhausted without serious consequences. This inquiry involves a consideration of the rate at which the oxygen is replenished from the atmosphere, for it is evident that after reducing the amount of dissolved oxygen to a certain point the rate of draft must not exceed the rate of replenishment.

Normal Quantity of Oxygen in Harbor Water. The amount of dissolved oxygen present in the water of a tidal harbor consisting of half sea water and half land water is 6.20 cubic centimetres per litre at 18 degrees centigrade. According to Letts and Adeney, the oxygen can be reduced to 3.45 cubic centimetres per litre, temporarily, at least, without danger of killing fish. Below this point it is unwise to exhaust the oxygen, due reference being had not only to the importance of fishing interests but also to the necessity of maintaining a wide margin of safety against the exhaustion of oxygen and the consequent production of putrefactive odors.

The rate of absorption of oxygen from the atmospheric air varies, according to Letts and Adeney, between 0.08 c.c. per litre per hour for sea water and 0.03 c.c. per litre per hour for land water at ordinary summer temperatures, and may be taken as 0.055 c.c. per hour for water such as that in the harbor of New York when the latter contains equal parts of sea water and land water.

The experimental conditions under which the above data are founded were obtained in breaking the surface of the waters either by a discharge of air three inches below the surface or by a mechanical stirrer. The waters of New York harbor are not ordinarily so much broken by the wind action. Assuming, however, that these favorable conditions do obtain it appears that an admixture of sewage which would not cause a greater draft upon the oxygen than 0.055 c.c. per litre per hour would not cause exhaustion and lead to putrefactive changes.

Theoretically Permissible Draft Upon the Oxygen. As a practical result of their studies, Letts and Adeney concluded that the dissolved oxygen in harbor waters is generally not in danger of being completely absorbed in forty-eight hours if the waters are mixed with sewage in proportion not greater than five per cent., provided that the solid matters have been separated by simple subsidence and the sewage does not contain appreciable quantities of directly oxidizable substances. This opinion is in accord with American experience where sewage has been discharged into rivers.

The studies made in America have shown that to avoid exhaustion of oxygen the dilution must be in the proportion of, at least, 20 to 25 parts of water to one part of ordinary sewage, although there may be conditions where nuisance may arise where the dilution amounts to nearly 50 parts of water to one part of sewage.

Whether sea water will absorb more sewage than land water without producing a nuisance has not yet been definitely determined in a practical way, although it seems certain that land water, gallon for gallon, is capable of disposing in a normal manner of more sewage than will sea water. It is worth bearing in mind in this connection that sea water, when saturated with oxygen, contains nearly 20 per cent. less oxygen than land water under the same conditions.

Amount of Oxygen in the Water of New York Harbor. The investigations of the Metropolitan Sewerage Commission of New York have shown that a substantial reduction in the normal amount of dissolved oxygen exists in the waters of New York harbor. As might be expected the draft upon the oxygen is greatest in the inner part of the harbor, that is, north of the Narrows, where the proportion of sewage to water is greatest.

In the Hudson river, above the city limits, in the East river beyond Hell Gate, and in the harbor outside the Narrows the quantity of oxygen available for the disposal of sewage matters is normal or nearly so.

In some of the more restricted parts of New York harbor there is practically no dissolved oxygen to be found in the waters. The waters of Newtown and Gowanus creeks are practically devoid of oxygen, as are those of Wallabout canal and the Passaic river.

More significant still, because of the larger body of water involved and the greater importance of the neighboring territory affected, is the condition of the Harlem river. The Harlem near its confluence with the East river has less than one-quarter of the amount of dissolved oxygen which it should possess and the river is markedly deficient in oxygen from end to end.

Zones Where Oxygen Is Depleted. With reference to the three main channels into Upper New York bay, there is found a gradual decrease of dissolved oxygen as one proceeds from the ocean inward.

First, with respect to the main ship route, *i. e.*, via the Lower bay, Narrows, Upper bay and Hudson river. Table VII shows the depletion in regular order to the Upper bay and then a better condition proceeding up the Hudson.

TABLE VII

DISSOLVED OXYGEN IN THE HARBOR WATER PROCEEDING FROM THE LOWER BAY UP THE HUDSON RIVER

Channel	Per Cent. Saturated With Oxygen
Lower bay	97
Narrows	83
Upper bay	67
Hudson to Spuyten Duyvil.....	72
Hudson north of Spuyten Duyvil.....	83

Table VIII shows a very decided depletion up the Harlem with an improved condition out of the Sound end of the East river. The actual figures for the Harlem and the lower East river are already at, or very close to, the absolute lower limit required by fish life.

TABLE VIII

DISSOLVED OXYGEN IN THE HARBOR WATER PROCEEDING FROM THE LOWER BAY UP THE EAST RIVER

Channel	Per Cent. Saturated With Oxygen
Lower bay	97
Narrows	83
Upper bay	67
East river to Hell Gate.....	65
Harlem river	55
East river to Throgs Neck.....	86

DATA COLLECTED

TABLE IX

DISSOLVED OXYGEN IN THE HARBOR WATER PROCEEDING FROM THE LOWER BAY UP THE
PASSAIC RIVER

Channel	Per Cent. Saturated With Oxygen
Lower bay	97
Narrows	83
Kill van Kull.....	79
Newark bay	76
Passaic river	6.4

The above figures are averages of the oxygen found at various depths and of conditions of tidal currents. Samples were taken in the centre of the channel.

Fish cannot thrive in water when the oxygen dissolved therein has been reduced to about 55 per cent. saturation, from which fact it is to be noted just how bad the East and Harlem rivers have grown to be.

Considering the waters as a whole, somewhat less oxygen is found at the surface than through the depth of the water, but the difference is generally not great.

Samples taken on flood tide show the influence of bringing in the water laden with dissolved oxygen. In practically every case the waters of a flood current have more dissolved oxygen than those of the corresponding ebb current. Table X shows that with the exception of the Harlem and Sound end of the East river there is from 4 to 18 per cent. more oxygen to be found in flood currents than in ebb currents.

TABLE X

DISSOLVED OXYGEN IN THE WATER DURING EBB AND FLOOD CURRENTS

Place	Per Cent. Saturated with Dissolved Oxygen	
	Flood	Ebb
Lower bay	100	95
Narrows	92	74
Upper bay	78	64
Hudson river to Spuyten Duyvil	76	66
Hudson river above Spuyten Duyvil	84	83
East river to Hell Gate	69	60
East river, Hell Gate to Throgs Neck	80	92
Harlem river	55	56
Kill van Kull	82	78
Newark bay	78	74
Arthur Kill	100	73

The Supply of Oxygen. The absorption of atmospheric oxygen by water proceeds very rapidly from the surface downward when once the oxygen has penetrated the surface, according to Letts and Adeney. These authors found that as soon as oxygen was dissolved by the water at the surface it was drawn rapidly throughout the depth of the water, the reason apparently being some unexplained process of gravitational streaming. The dissolved oxygen shows practically no tendency to accumulate near the surface, but passes almost as quickly through it as it is dissolved. In consequence of this peculiar phenomenon the aeration of sea water is nearly always uniform through its depth. There is a slight tendency in land water for the oxygen to accumulate at the top.

Sewage Saturation and the Production of Odors. By whatever process the oxidation of sewage matters proceeds, that progress is satisfactory only so long as a sufficient supply of oxygen is available. When the dissolved oxygen becomes exhausted, putrefactive changes set in and with these offensive odors are produced. These odors are particularly disagreeable when putrefaction takes place in the presence of sea water. In this case the avidity of the micro-organisms for oxygen is so great that various compounds of oxygen, which under ordinary circumstances are stable, are destroyed for the oxygen which they contain. As a consequence of this action gases, of which sulphuretted hydrogen is an example, are released. These gases escape in bubbles from the water and often give rise to offensively smelling odors as already noted. As compared with fresh water streams, lakes and other bodies of inland water, New York harbor is not a favorable place for the disposal of sewage so far as this question is concerned.

Relation Between Diffusion and Digestion of Sewage. It is evident from the foregoing, that, in order to employ the great volume of water flowing in and out of New York harbor so as to dispose of sewage without producing a nuisance there is required the fulfillment of, at least, two main conditions:

First, the practicability of diffusing the sewage with the water.

Second, the quantity of sewage must not be too great for the quantity of water into which it is discharged.

The presence of minute particles of suspended matter in the volume of the main tidal currents is in itself the least objectionable feature connected with the disposal of sewage by diffusion. But the accumulation of these small particles form extensive and foul-smelling masses of sludge and render large arms of the harbor water black and foul smelling.

Large particles which float upon the surface are offensive to the sight and break up to form the smaller particles which are carried in suspension. They add to the accumulations of sludge on the bottom. Yet the total quantity of the large suspended

particles is not great when compared with the total quantity of solid organic matter carried beneath the surface.

The heavy particles carried by sewage, notably sand and other solid substances which rapidly deposit near sewer outfalls, are for the most part inorganic in composition and contribute but little to the offensiveness of the water. Yet as Dunbar¹ has remarked, it may be a mistake to regard mineral matter like sand as unobjectionable because of its inorganic composition. The mineral particles are covered with organic matters which are putrescible. When sand from sewers accumulates in quantity it may give rise to extremely unpleasant odors.

The grease which flows upon the surface or is deposited upon the harbor bottom gives rise to peculiar and unpleasant odors and is unsightly in appearance, but its worst effect is local. It is not to be compared in offensiveness with solid floating particles of excrement, or in potential harm with the other organic impurities which are in solution and suspension in the harbor waters.

The organic matters which are in solution and the solids which are capable of producing these organic matters under suitable conditions of putrefaction constitute the principal objection which may be raised against the discharge of sewage into New York harbor, except in so far as public health is directly connected with this subject. This connection lies chiefly in the bacterial condition of the water and the uses to which the water is put by the public in bathing and cultivating oysters and will not be dealt with in this chapter.

The whole problem of the disposal of sewage into New York harbor, therefore, resolves itself largely into a question of how and to what extent diffusion and digestion may be carried on with the certainty of producing uniformly satisfactory results. The remaining portion of this chapter will, therefore, be devoted to a discussion of some of the principles of diffusion and to a brief description of a number of experiments made by the Metropolitan Commission in order to obtain a better knowledge of the circumstances under which the diffusion and digestion of sewage in New York harbor can be made to take place.

SECTION IV

EXPERIMENTAL STUDIES OF THE DIFFUSION AND DIGESTION OF SEWAGE IN NEW YORK HARBOR

The relation between diffusion and digestion of sewage in water is close, although it is by no means always obvious. A thorough intermixture of the sewage with the

¹Principles of Sewage Treatment by Prof. Dr. Dunbar, 1908, p. 47.

water is indispensable for the assimilation of the liquid organic matters, but it is not necessary in order that a rapid liquefaction of the organic solids should take place.

DIFFUSION OF SEWAGE IN NEW YORK HARBOR

Setting aside for the present the question of mechanical transportation of sewage particles from a sewer outfall through the displacing action of tidal currents, we will proceed to consider some general facts concerning the dispersion and diffusion of sewage in water.

Definition of the Terms Dispersion and Diffusion. The term dispersion implies a separation and scattering of solid particles, while diffusion refers especially to an intermixture of liquids. When dispersion and diffusion proceed satisfactorily the water of a harbor which receives sewage becomes uniformly charged with the solid and liquid sewage matters. When diffusion and dispersion do not take place satisfactorily the sewage may flow in a mass upon, alongside or within the natural body of water.

It is sometimes erroneously assumed that diffusion is everywhere and at all times proceeding rapidly in natural bodies of water and that sewage becomes intermixed and invisible as soon as it reaches the water into which it is discharged. The fact is that no such rapid and general intermixture of water and sewage ordinarily takes place.

Effect of Discharging Sewage at the Surface. Where sewage is discharged at the surface of a harbor diffusion proceeds slowly. The sewage flows away upon the surface and, in the absence of currents capable of producing diffusion, a stratum of heavily contaminated water lies at the surface, while the main body of water flowing below remains relatively unpolluted. There are many examples of this method of discharge, with all its unsatisfactory consequences in The City of New York and neighboring municipalities.

Effect of Discharging Sewage Below the Surface. When sewage is discharged beneath the surface of harbor water it usually rises to the top close to the point where it is discharged. It spreads out upon the surface as though it had been discharged there. Only the action of comparatively rapid currents of tidal water or the discharge of small quantities of sewage at great depths below the surface is apparently capable of producing sufficient diffusion to prevent the appearance of sewage upon the surface. Judging by the experience of the few cities which have attempted to discharge sewage beneath the surface of harbor waters the advantages gained by this method of disposal are likely to be incommensurate with the increased expense of pumping the sewage and constructing the sewer outfalls. The experiences of Boston and the Metropolitan Sewerage Commission of Massachusetts in discharging sewage beneath the surface of Boston harbor point to an example which should be avoided.

There are three outlets from the Boston and metropolitan sewerage systems and all are located in the outer harbor. The Boston outlet is at Moon Island; the outlet for the north metropolitan district is at Deer Island, and the outlet for the high level, or south metropolitan district, is at Peddocks Island.

Conditions at the Boston Outlets. At the Moon Island outlet about 40,000,000 gallons are discharged from the storage tanks in about two hours on each outgoing tide. The discharge takes place at the surface of the water. The harbor becomes discolored over an area of about 1,000 acres.

At the Deer Island outlet a continuous flow of 48,000,000 to 72,000,000 gallons of sewage a day covers an area, at the ebb tide, about one and one-quarter miles in length by two-fifths of a mile in width at the widest place. The outlet is at low water or a little below it. Under average conditions the area covered is about 250 acres.

The Peddocks Island outlets are located in a deep tidal channel where the current flows at a maximum velocity of nearly four miles per hour. The Moon Island and Deer Island outlets discharge into maximum current velocities of about two and four miles per hour respectively. The sewage rises rapidly from a depth of 30 feet below the surface of the harbor water at low tide and is imperfectly dispersed and diluted before it reaches the top.

Immediately over the outlet on an occasion when the Metropolitan Sewerage Commissioners of New York visited it, the sewage boiled up like a large spring, the agitation being violent over a circular area of a diameter of 15 feet. The odor was noticeable at a distance of 500 or 600 feet from the outlet. The quantity of sewage being discharged on this occasion was about 40,000,000 gallons per day and the population served about 400,000. The sewage had been passed through deposit sewers and coarse screens to take out such suspended matters as could be removed in this way before the sewage was discharged into the harbor.

The water in the vicinity of the outlet had a grayish appearance. There was much floating matter consisting of balls of grease, scum, shreds of paper and similar refuse which could be seen for several hundred feet from the outlet in all directions, and on the leeward side of the outlet, 1,000 feet away. The sleek on the surface of the water was plainly noticeable for at least one mile in the direction in which the tidal current was running. The location of the outlet was indicated by the smoothness of the water and by a flock of gulls which hovered about it.

Ascent of Sewage in New York Harbor. From a theoretical standpoint it is evident that diffusion between two such liquids as sewage and harbor water may be materially affected by the difference in specific gravity which exists between the two. Some idea of the extent of this effect can be had from the fact that a cubic foot of land



Interior of the Commission's Main Laboratory. Here such analytical work was done as could not be carried out on the floating laboratory



Tender Used in Experiments on Diffusion and Float Observations. With a double crew and force of observers the floats were followed continuously night and day

water is about one and three-quarters pounds lighter than an equal volume of sea water. In consequence of this difference, every cubic foot of sewage which is discharged beneath the surface of sea water will be urged toward the top with a force of about one and three-quarters pounds. The upward moving force is less than that stated according to the proportion of land water to sea water which is present in the harbor.

It is possible to approximately express the rising velocity of a volume of sewage discharged beneath the surface of a quiet body of water of greater specific gravity by the mathematical formula

$$V = K \sqrt{2gh}$$

in which V is the velocity of the ascending sewage, and h is the head corresponding to the buoying force. From this formula it is evident that the rate of ascent varies as the square of the difference in specific gravity. An important point to remember here is that the velocity of ascent will be doubled when the buoying force is multiplied four times.

It is impracticable to calculate the velocity of ascent by means of this or any other formula without knowing the shape of the ascending column of sewage. The rate of ascent will depend upon the frictional resistance which the ascending column of sewage offers to the surrounding body of water and, consequently the shape of that column must be known in order to calculate the rate.

Flotation Experiments With Solid Objects. In order to get a better idea of the rate of ascent of sewage in harbor water a series of experiments was made by the Metropolitan Commission with solid wooden balls released at a sufficient depth beneath the surface of a quiet body of water to enable the rate of ascent to be noted accurately.

The balls were about four inches in diameter. They were coated with shellac so as to be impervious to water and were weighted so as to have the specific gravity of land water. Four series of experiments, including the observation of 18 balls, were made in mixtures of land and harbor water with the following results: The rate of ascent was 0.30 feet per second in 75 per cent. land water, 0.45 feet per second in 44 per cent. land water and 0.50 feet per second in 16 per cent. land water. These rates probably show the maximum velocity which can safely be expected when the rising substance is sewage.

Experiments on the Ascent and Diffusion of One Liquid in Another. A number of experiments were made by the Metropolitan Commission to obtain practical information concerning the circumstances under which sewage would and would not diffuse in harbor water. In general the method used in making these experiments was as follows. The water or sewage to be discharged was strongly colored with a dye.

The discharge was then regulated to take place in a continuous stream under prearranged conditions as to velocity and volume beneath the surface of the water with which it was to diffuse. The discharging current having been made visible by the dye it only remained to study the phenomena of diffusion by observing the colored water.

Various dyes were experimented with in order to determine the most suitable for this use. It was desirable that the dye should be not only bright and clear when mixed with sewage or water but it should not be so altered in color through dilution or through chemical action with matters present either in the sewage or the water into which the sewage was discharged as to become indistinguishable. It was necessary that it should not add materially to the specific gravity of the water. The dye should not cause a precipitation of any of the matters with which it came in contact and it should not be so expensive as to preclude its use on a large scale.

After many tests two dyes, one known as uranine and the other special scarlet, were selected. The uranine, a sodium salt of fluorescein, was found to be particularly suitable. This dye could be detected by sight in dilutions of one to 30 million parts of water. When a bucketful of dyed sewage was thrown upon the surface of the harbor it could be seen at a distance of a quarter of a mile. It might remain visible for 20 minutes or more.

The quantities of colored water or sewage discharged varied between 300 gallons and 56,000 gallons according to the requirements of the experiment. The harbor water varied somewhat in salinity. It usually contained about 25 per cent. land water and 75 per cent. sea water.

The current into which the water or sewage was discharged varied from a little less than one foot per second to three feet per second.

Most of the large scale experiments were carried on near Robbins Reef in Upper New York bay. A few were made near Mt. St. Vincent in the Hudson river and three were carried on at the Sound entrance to the East river near Stepping Stones Light.

In all the experiments the specific gravity and temperature of the sewage and water dealt with were determined by a salinometer devised by the commission. The details of each experiment were timed and recorded. Sketches were made with suitable measurements to show the adjustment of apparatus and the phenomena observed. Each experiment was carefully and fully reported with the inferences and opinions which it seemed safe to draw from the results.

The first experiments were made in the Commission's laboratory upon a small scale. Later, in order to carry out these experiments on a larger scale, a tank courteously placed at the Commission's disposal by the management of the New York Aquarium was used. The Aquarium tank measured eight feet in length, four feet in

depth and four feet in width. It had a plate glass side through which the phenomena of diffusion and other conditions in the tank could be observed. The tank was supplied with land water and harbor water, according to the requirements of the experiment.

The experiments on the largest scale were made with boatloads of dyed water and dyed sewage. The dyed water was contained in casks of several hundred gallons capacity. Three of these casks were located upon the Commission's floating laboratory and connected with a steam pump which was capable of discharging the dye through a suitable hose at any required depth.

In one instance a small tank steamer was used and in another a pontoon holding 60,000 gallons with an eight-inch centrifugal pump were employed. In these largest scale experiments most of the Commission's employees took part as observers. Most of the observers were located on boats which were used in carrying on the experiments, but in some cases an observer was placed upon a lighthouse or other point of vantage at a considerable elevation above the water in order to observe any effects which might escape the observers closer at hand. The total number of experiments made was 103. Of these, 66 were on a large scale.

Facts and Opinions Drawn from the Experiments. Following are some of the principal facts and deductions drawn from these studies.

Sewage when discharged into sea water rises in a mass unless intermixed through the mechanical action of currents.

Sewage rises through sea water because of the difference in specific gravity between the two liquids. Differences in temperature produce differences in specific gravity, and it is this latter difference which need alone be considered in studying the conditions under which sewage will rise.

Sewage appears to be practically in equilibrium when discharged into a mixture of about 85 per cent. land water and 15 per cent. sea water, that is, it will not rise or fall through the water into which it is discharged.

When sewage is allowed to stand at the top of a perfectly quiet body of water diffusion occurs at once if the water is land water, but not until after 48 hours if the water is a mixture of equal parts land water and sea water.

When sewage is discharged through an orifice into and beneath the surface of a quiet body of water currents are set up in the latter which help produce an intermixture between the two fluids. The force of these currents varies directly with the velocity of the discharging current and the volume of discharge.

Sewage discharged through an orifice into and beneath the surface of a quiet body of water of the same specific gravity does not mingle instantaneously with the surround-

X

ing water. Some diffusion takes place from the outside edges of the discharging stream but intermixture proceeds chiefly after the discharging stream has lost its initial velocity. In other words, time is an important factor in the mixing process.

If directed vertically upward, the discharging stream flows toward the top in a gradually enlarging column. At the top the sewage spreads out thinly upon the surface. Diffusion gradually takes place downward from the surface.

If discharged horizontally, the inflowing sewage at first preserves its integrity for a considerable distance, depending upon the initial velocity at the orifice, and then rising upward spreads out in a layer at the surface. Diffusion takes place in this case downward from the gradually enlarged column and from the surface layer.

Sewage discharged into a quiet body of harbor water consisting of 40 per cent. land water and 60 per cent. sea water rises toward the surface, irrespective of the direction of discharge from the orifice, and spreads out upon the surface in a large thin layer. Discharged in a horizontal direction, at a velocity of one and one-third feet per second, the upward motion is not retarded perceptibly.

The inflowing volume is larger and longer when the discharge is horizontal than when the discharge is upward or downward, and for this reason a horizontal discharge of sewage facilitates diffusion.

Of the 66 large-scale experiments about one-half were successful in showing conditions which should be avoided in discharging sewage beneath the surface of harbor water. In 29 cases the sewage came at once to the surface; in 31 cases no effect was visible; in six cases the result was doubtful. The sewage was discharged at depths varying between five and 62 feet below the surface of the water.

In one case, at Robbins Reef, when 600 gallons of water were discharged at a depth of 40 feet into a current of one foot per second it came to the surface. In another instance when 15,600 gallons were discharged at the same place and under what seemed to be similar conditions it did not appear at the surface.

The sewage used in the experiments just described was obtained at the mouth of one of the principal sewers of New York. The water in all but the large-scale experiments was taken from the City of New York public water supply; that used in the experiments where boatloads were employed was from the public drinking water supplies of Communipaw, N. J., and Stapleton, S. I.

There was nothing unusual about the sewage employed to distinguish it from other samples of fresh, normal sewage which might have been obtained in this or any other American city. Such differences as might exist between the sewage and clean water, which was sometimes used in the experiments in place of sewage, could affect the results only in so far as they altered the specific gravity of the fluids considered.

The specific gravity of the samples of sewage and water experimented with as sewage was the same in every case.

The grease and gas which would help carry sewage to the surface and the solid and semi-solid matters which would help take it down were not taken into account in these experiments. These substances were too variable and uncertain in composition and effect to reckon with. At the same time it is evident that in some cases the gas produced or entrained in sewage may exert a decided effect in carrying sewage to the top of a natural body of water below whose surface the sewage is discharged, while the grease, not being miscible with the water or entering into chemical combination with any of its ingredients, would rise to the surface and remain there. In so far as these conditions would be likely to affect the result of the experiments they would make diffusion more unsatisfactory than the experiments indicated.

DIGESTION

Digestion experiments were undertaken in order to show the rate at which sewage solids became liquefied in the harbor water. They showed, among other things, that the rate depends upon the condition of the water into which the solids are placed. The solids disappear more rapidly in polluted water than in clean water.

Conditions Under Which the Experiments Were Made. The most instructive experiments, and the only ones which need be mentioned here, were carried on by putting various organic solid substances in receptacles which were then placed in trays, with suitable weights, and sunk in the water. The receptacles were several inches in diameter, made of glass or metal, and were covered with wire netting in order to prevent the bodily removal of the solid substances by fishes. The receptacles, and the trays which contained them, had sides high enough to prevent active currents from meeting the solid matters and yet not so high as to prevent a proper circulation of water. The solid objects were allowed to remain submerged for varying periods of time in order to give them a sufficient opportunity to disappear by digestion. The experiments were carried on in the New York Aquarium and in the open harbor water at the Battery.

Facts and Opinions Drawn from the Experiments on Digestion. The experiments carried on in the relatively clean waters of the Aquarium and in the polluted water of the harbor gave different results. Objects of solid organic composition that would rapidly decompose in sewage, sewage sludge or water badly polluted by sewage, when placed in comparatively pure water remained almost unattacked. A period of time which was sufficient for the solids to entirely disappear in polluted water or sludge was insufficient to produce visible effect when placed in clean water.

Much of the organic matter placed in the water at the Battery became completely decomposed in three or four weeks. Part of the residue showed signs of beginning decomposition. Proteid and albuminous substances were most easily decomposed and carbohydrates disappeared almost as readily. Fats were not much changed and bones and eggshells were unchanged. Glumes and fibrous matters seemed to be in almost the same condition as when put into the water and the same was true of hair. Hemp, cotton and wool fibres were broken up into finer pieces, but otherwise unchanged. Human feces entirely disappeared as such. Tissue toilet paper was completely dissolved in three weeks. Newspaper proved very resistant and could plainly be distinguished at the end of three months.

During the course of the experiments it was found that sewage sludge deposited from the water into the receptacles which were placed in the harbor water at the Battery. The sludge was soft and oozy at the surface and more concentrated as the depth increased. The top layer was of a dirty, grayish brown color. Below the surface the sludge was black. The difference in color between the surface and the sludge beneath the surface has frequently been noticed in the Commission's studies of the deposits on the bottom of New York harbor. The black coloration is due, apparently, to the formation of sulphide of iron brought about by the deoxidation of iron compounds by anaerobic bacteria. The grayish surface layer is probably produced by an oxidation of the inorganic matters and of the iron sulphide. This oxidation is caused by the activities of bacteria which have the power to abstract dissolved oxygen from the water and unite it to partly mineralized substances.

CHAPTER XI

RELATION BETWEEN THE POLLUTION OF THE HARBOR WATERS AND PUBLIC HEALTH

SECTION I

INFECTION OF THE HARBOR WATERS

In the following pages are given data to show the probability of a connection between the pollution of the waters in the metropolitan district and the spread of infectious diseases. Owing to the fact that it is usually very difficult to establish proof of the development of an individual case of infectious disease from its cause much reliance must be placed on observations of a general nature.

INFECTIOUS AND CONTAGIOUS DISEASES IN THE METROPOLITAN DISTRICT

In the metropolitan district, with its large and cosmopolitan population, many forms of transmissible disease are always present. These are classified by The City of New York Department of Health into contagious and communicable diseases. The former are directly acquired by contact and the latter more indirectly by the contamination with specific germs of various objects and of articles of food and drink. Through these agencies the germs may be introduced into the human organism and thereby cause disease.

Greater New York. During the year 1908 there were reported to The City of New York Department of Health 87,161 cases of contagious diseases, including diphtheria and croup, measles, scarlet fever, whooping cough, chickenpox, German measles and mumps. The records of the cases for that year are shown in Table I.

TABLE I
NUMBER OF CASES OF CONTAGIOUS DISEASES REPORTED IN 1908 IN THE CITY
OF NEW YORK*

	Borough					
	Manhattan	Brooklyn	The Bronx	Queens	Richmond	Total
Population, 1900.....	1,850,093	1,166,582	175,422	152,999	21,441	3,847,557
Diphtheria and croup.....	10,263	5,451	1,648	885	284	18,531
Measles.....	18,264	8,707	4,612	1,897	696	34,176
Smallpox.....	6	6	2	3	..	17
Scarlet fever.....	12,057	8,121	2,529	1,296	417	24,420
Whooping cough.....	467	414	133	36	122	1,172
Chickenpox.....	2,781	2,045	710	297	158	5,991
German measles.....	544	152	53	43	31	823
Mumps.....	1,372	489	40	16	114	2,031
Totals.....	45,754	25,385	9,727	4,473	1,822	87,161

* Quarterly reports of the Department of Health of The City of New York, 1908.

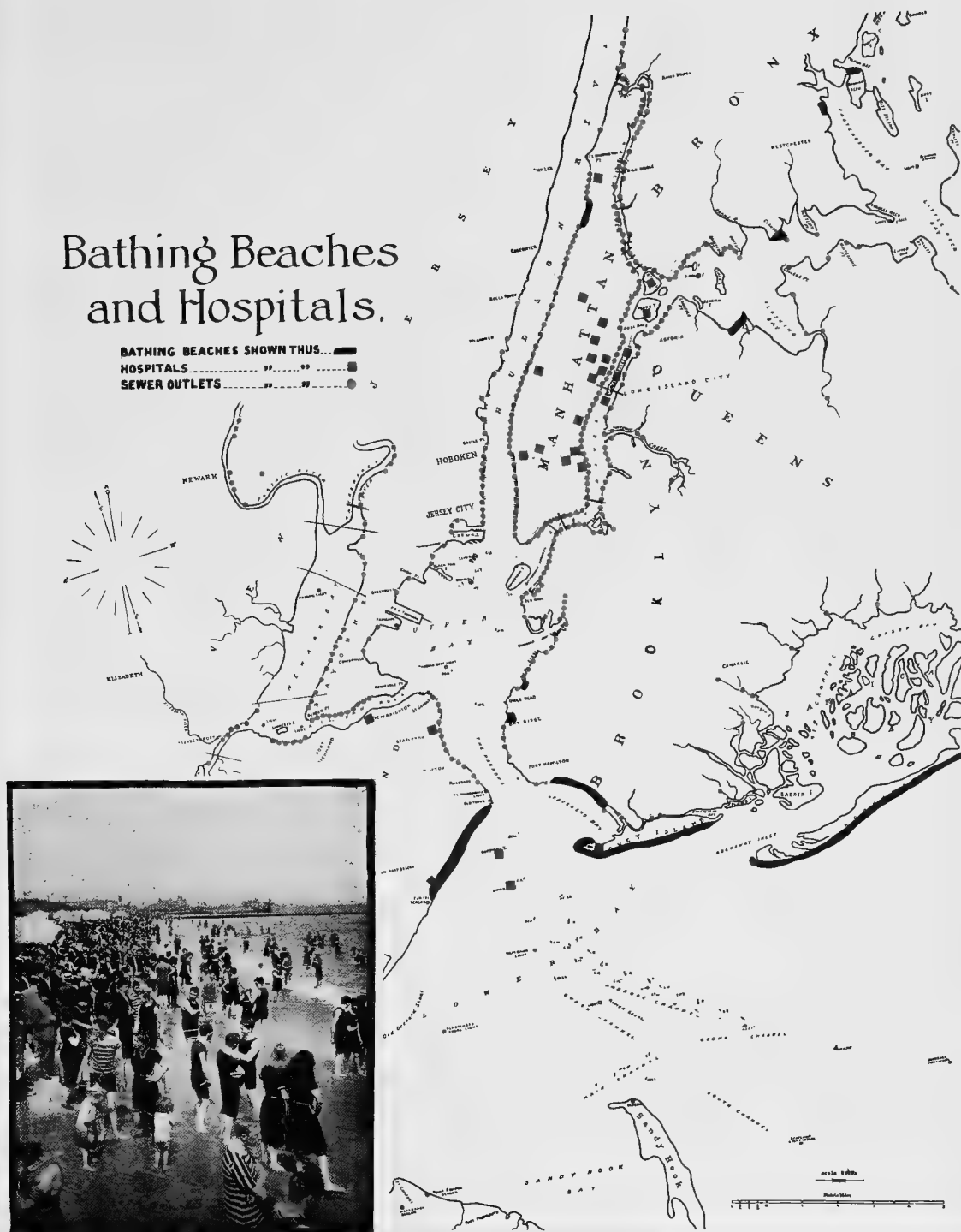
Of these, the causative germ of diphtheria only has been discovered and no evidence has yet been published of water borne epidemics of any of the other diseases mentioned, although it is known that both scarlet fever and diphtheria have been transmitted by milk.

There were also reported 26,224 cases of communicable diseases, including 21,782 of tuberculosis of all varieties, 3,014 of typhoid fever, 402 of meningitis, 287 of malaria, 609 of erysipelas, and 130 of septicaemia. The reports of typhoid were not complete.

The detailed data are given in Table II.

Bathing Beaches and Hospitals.

BATHING BEACHES SHOWN THUS: —
HOSPITALS: —
SEWER OUTLETS: —



Bathing Beaches and Hospitals. Many hospitals are located on the waterfront and feel injurious effects from the sewage discharged into the nearby waters



Bathing Beach, Recreation Pier, Oyster Beds and People Fishing in Upper New York Bay

TABLE II
CASES OF COMMUNICABLE DISEASES REPORTED AS TREATED AT HOSPITALS AND AT HOME,
IN 1908, IN THE CITY OF NEW YORK

	Borough					
	Manhattan	Brooklyn	The Bronx	Queens	Richmond	Total
Tuberculosis—						
Home cases.....	12,034	3,748	1,188	168	200	17,338
Hospital cases.....	3,260	811	203	34	136	4,444
Typhoid Fever—						
Home cases.....	695	596	176	99	26	1,592
Hospital cases.....	760	408	114	101	39	1,422
Meningitis—						
Home cases.....	129	94	16	10	8	257
Hospital cases.....	94	36	10	2	3	145
Malarial Fever—						
Home cases.....	93	34	38	12	6	183
Hospital cases.....	49	26	6	23	0	104
Erysipelas—						
Home cases.....	225	80	8	15	8	336
Hospital cases.....	118	140	9	1	5	273
Septicaemia—						
Home cases.....	7	18	10	0	0	35
Hospital cases.....	51	23	11	7	3	95
Total Home cases.....	13,183	4,570	1,436	304	248	19,741
Total Hospital cases.....	4,332	1,444	353	168	186	6,483
Total All cases.....	17,515	6,014	1,789	472	434	26,224

Westchester County. The sewage from that portion of Westchester County lying within the metropolitan district, the population of which was 126,985 in 1905, drains directly or indirectly into the harbor waters of New York. Records of all the cases of contagious and communicable diseases in this district are not available, but may be estimated from the number of deaths for the year 1908, as given in the report of the New York State Department of Health for that year. Assuming the mortality from typhoid as 8 per cent. of the cases, scarlet fever as 5.5 per cent., measles as 2.8 per cent., diphtheria 10 per cent., and pulmonary tuberculosis as each case living at least three years, there should have been in Westchester County approximately 987 cases

of typhoid, 1,463 of scarlet fever, 1,643 of measles, 909 of diphtheria and 1,857 of pulmonary tuberculosis. The detailed data are given in Table III.

TABLE III
NUMBER OF DEATHS AND ESTIMATED NUMBER OF CASES OF COMMUNICABLE DISEASES IN
WESTCHESTER COUNTY, NEW YORK IN 1908

	Population State Census, 1905	Typhoid fever	Scarlet fever	Measles	Whooping Cough	Diarrhoea	Tuberculosis	Total
Westchester County	28,950	60	45	28	13	332	410	888
Eastchester	3,986	1	..	4	..	8	1	17
Greenburgh	1,863	..	..	5	..	2	10	17
Mt. Vernon	25,006	2	4	6	4	39	35	90
New Rochelle	20,480	7	4	1	..	21	24	57
Pelham	1,840	..	1	..	..	3	..	4
Scarsdale	1,018	..	..	..	..	1	2	3
White Plains	12,129	2	1	..	..	12	18	33
Yonkers	69,503	7	24	2	3	147	116	299
Total	164,775	79	79	46	20	565	619	1,408
Percentage Mortality, the City of New York, 1908		8%	5.4%	2.8%	2.6%		3%	
Estimated Number of cases in above men- tioned county and towns		987	1,463	1,643	769		1,857	

Nassau County, New York. There is a small part of Nassau County, including the town of North Hempstead, which had a population of 1,411 in 1905, the sewage of which also drains into the metropolitan waters.

New Jersey. That portion of New Jersey which lies within the limits of the metropolitan district, including an area of approximately 350 square miles in the counties of Bergen, Essex, Hudson, Middlesex, Passaic and Union, had in 1905 a population of 1,203,387. In these counties, in which are situated Jersey City, Hoboken, Newark, Paterson, Passaic, Orange, Elizabeth and Rahway, and numerous small towns and villages, only the number of deaths during the year 1907 could be obtained. But based on the mortality of the various diseases assumed for New York for that year there should have been in these counties approximately 2,925 cases of typhoid, 5,318 of measles, 4,777 of scarlet fever, 4,440 of diphtheria and 8,904 of tuberculosis.

The detailed data are given in Table IV.

TABLE IV

DEATHS AND ESTIMATED NUMBER OF CASES OF CONTAGIOUS AND COMMUNICABLE DISEASES IN COUNTIES IN NEW JERSEY, OF THE METROPOLITAN DISTRICT IN 1907

	Population by State Census, 1905	Deaths, 1907 Typhoid fever	Measles	Scarlet fever	Whooping cough	Diphtheria	Tuberculosis	Total
Bergen County.....	100,003	14	8	5	17	19	132	195
Essex County.....	409,928	86	19	52	46	119	1,059	1,381
Hudson County.....	449,679	75	63	146	46	167	1,113	1,610
Middlesex County.....	97,036	20	4	9	15	30	141	219
Passaic County.....	175,058	22	18	25	9	44	302	420
Union County.....	117,211	17	5	21	20	65	221	349
Total.....	1,348,915	234	117	258	153	444	2,968	4,174
Mortality, County of New York, 1907.....		8	2.2%	5.4%	2.6%	10%	× 3	
Number of cases in New Jersey Counties.		2,925	5,318	4,777	5,884	4,440	8,904	

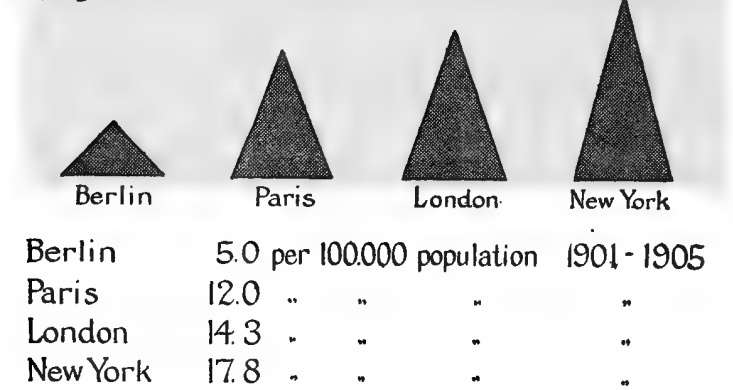
TUBERCULOSIS AND TYPHOID FEVER

Means of Disinfection. Although the discharges from patients suffering from any of the various contagious diseases may be capable of transmitting their disease, yet little is known about the mode of transmission apart from contact.

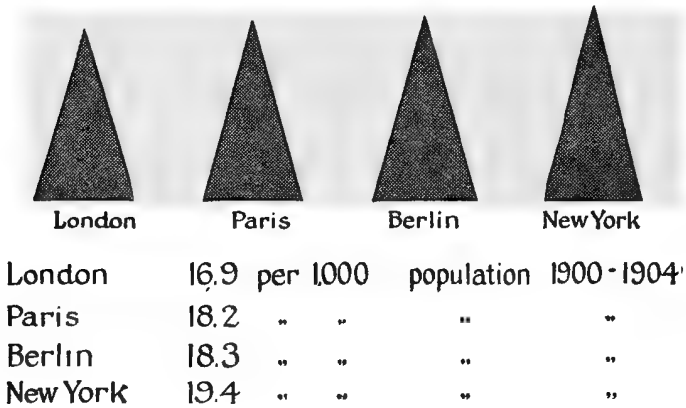
In considering the effect of the harbor waters on health the two most important communicable diseases are tuberculosis and typhoid fever. Of the 26,224 cases of communicable diseases reported to the New York Department of Health in 1908, 24,796, or 94 per cent., were tuberculosis and typhoid fever, tuberculosis comprising 87 per cent. of the number.

A large amount of accurate knowledge is available as to the method of transmission of these diseases. Tuberculosis is caused by the inhalation of tubercle bacilli, which come from the sputum of individuals suffering from tuberculosis and from the ingestion of food contaminated with tubercle bacilli. The tubercle bacilli are found in the sputum of patients who have pulmonary tuberculosis, in the feces of those who have intestinal tuberculosis and frequently in the feces of those who have pulmonary tuberculosis. Tubercle bacilli exist in the urine of patients suffering from tuberculosis of the genito-urinary tract. Typhoid bacilli occur in the stools and urine of patients who have typhoid fever, in the stools and urine of convalescents from this disease and in the excretions of some persons who are apparently in good health.

Typhoid Fever Death Rates



General Death Rates



Typhoid fever is always present in the City of New York. The death rate per 100,000 inhabitants from typhoid during the last eighteen years has averaged 18.5. While this figure is lower than that for many other American cities, it does not compare favorably with the rate for well-regulated foreign cities as shown in Table V.

TABLE V.
TYPHOID FEVER DEATHS IN 17 CITIES PER 100,000 LIVING

Year	American Cities												Foreign Cities				
	Baltimore	Boston	Chicago	Cleveland	Indianapolis	Louisville	New York	Philadelphia	Pittsburg	St. Louis	Washington	San Francisco	London	Paris	Berlin	Vienna	Dresden
1898.....	37.1	33.	37.6	31.8	28.4	57.7	20.7	49.4	68.	16.5	60.6	16.7	13.	9.9	4.3	6.8	4.3
1899.....	30.1	29.4	26.	28.6	37.8	59.8	16.3	73.4	106.9	22.8	60.7	51.2	17.8	29.	4.1	4.1	7.3
1900.....	37.1	25.6	19.9	53.8	43.7	57.8	20.8	34.7	144.2	29.2	77.8	41.3	16.5	34.6	5.8	8.3	4.1
1901.....	28.7	23.8	29.8	34.9	33.1	46.	20.6	34.6	123.8	33.4	61.4	25.1	12.1	13.7	4.7	4.5	6.4
1902.....	42.	22.1	45.1	35.5	44.5	60.3	20.3	47.3	140.6	40.	79.1	29.6	12.8	....	2.7	3.	4.
1903.....	35.	20.5	32.1	115.	51.1	59.8	17.1	72.6	136.5	52.4	48.8	25.	8.6	10.4	3.2	3.9	5.3
1904.....	37.5	23.6	20.2	49.6	68.4	61.6	16.8	55.	139.4	37.9	47.	31.4	6.2	12.2	3.7	3.4	2.8
1905.....	35.7	20.8	16.5	14.9	30.2	49.4	16.	51.	107.9	22.6	48.2	23.9	5.2	....	5.3	4.4	3.7
1906.....	34.3	21.6	18.3	20.2	39.2	67.7	15.4	74.8	141.3	18.3	52.3	....	6.	11.	4.	5.	7.
1907.....	41.3	10.5	17.7	18.9	29.4	67.9	17.5	60.7	130.8	16.3	35.5	....	4.	10.	4.	3.	2.

If New York's typhoid death rate seems low as compared with the rates of other American cities, it appears high when compared with the rates of cities in northern Europe, as, for example, London, where the average rate from typhoid fever from 1898 to 1907 was 11.5, Berlin 4.2, Vienna 4.8 and Dresden 4.7. In Munich, Hamburg, Bremen and other German cities the rates were also far below that of New York.

In many European cities where typhoid formerly existed as it does to-day in America it has become a rarity. A case of typhoid fever admitted to the large city hospital in Munich in May, 1909, the first case of its kind since the previous September, was looked upon as a curiosity.

The low typhoid rates of foreign cities means better sanitary conditions than exist in the United States, especially better water supplies and better methods of sewage disposal.

The 4,176 cases of typhoid fever reported to the Health Department of The City of New York in 1907 were considered by the Department to be due to the following causes:

CAUSES OF TYPHOID FEVER IN THE CITY OF NEW YORK ACCORDING TO THE CITY DEPARTMENT OF HEALTH

Cases due to water.....	169
Cases due to milk.....	570
Cases due to oysters.....	113
Cases due to exposure to other cases.....	294
Cases due to out of town.....	966
Cases due to unknown causes.....	2,064
Total	4,176

Nearly 50 per cent. of the cases were acknowledged to have been caused by unknown agencies. It is not known where the oysters came from that caused the 113 cases, nor whether any of the 2,064 cases were among persons who had bathed in the harbor waters or were otherwise exposed to the polluted harbor. Were all the facts in these cases known it is possible that many might have been traced to the harbor water.

Longevity of Tubercle and Typhoid Bacilli. Tubercle bacilli have been found to remain virulent for from two to ten months according to Schill and Fischer,¹ Sormani,² Toma³ and Savitzky.⁴ In fluids the bacilli retain their virulence a shorter time. Schill and Fischer found that bacilli retained their virulence in decomposing sputum for 43 days. Galtier⁵ found them virulent after being two months in water. It has also been found that where there is a large growth of saprophytic bacteria the tubercle bacilli rapidly disappear. Cornet⁶ also found that under a covering of snow, and at times with a temperature as low as -10° C., tubercle bacilli retained their vitality as long as six weeks.

A large number of experiments have been made to test the longevity of typhoid bacilli in drinking water, but as there have also been a number of observations made upon the viability of typhoid bacilli in sewage and sea water, only these will be considered here. Giaksa⁷ found that typhoid bacilli lived for many days in sea water. Boyce and Herdman⁸ found that typhoid bacilli would live for a month in sea water. Foster⁹ and Freytag state that "Typhoid germs will live for a long time in sea water."

¹ M. Kals, G. A. Bd. II, 1884.

² *Italian d'Igiene*, Anno VIII, No. 56.

³ *Annale de Medicin* Vols. CCLXXV, p. 3, and CCLXXVII, p. 39, 1886.

⁴ *Med. Chron.*, Nov. 1890, p. 877, *ibid.* Bd. XI, p. 153, 1892.

⁵ *Compte rendre de l' Acad de Sc.* Tome CV, p. 231.

⁶ *Nothnagel's Encycl. of Medicine*, Volume on Tuberculosis, 1904.

⁷ *British Medical Journal*, 1895, Vol. I, p. 390.

⁸ Quoted by *Conn. Med. Record*, 1894, Vol. LXVI, p. 743.

⁹ Quoted by Klein, see note 5.

Lawes and Andrewes¹⁰ found that typhoid bacilli at 20° C. would live in sterile sewage about a fortnight. Klein¹¹ found that they would remain in sterile sewage three weeks, and if nitrates were added they existed in enormous numbers for eight weeks. Jordan, Russell and Zeit¹² found that typhoid bacilli lived in Chicago drainage canal water for two days and once for ten days. Russell and Fuller¹³ found them alive in water in which sewage was added from three to five days. McConkey¹⁴ found that typhoid bacilli could be recovered, after being introduced into crude sewage, for six days, but that they did not multiply and died more or less rapidly.

There is unanimous opinion that typhoid bacilli will live in sewage whether or not the sewage be sterilized before these germs are added; that typhoid bacilli do not usually multiply in crude sewage, but retain their vitality for some days, and that typhoid bacilli may live a considerable time in sea water.

Difficulties of Disinfection. Attempts are usually made in hospital practice to disinfect the discharges of all patients suffering from contagious and communicable diseases, but it is probable that these attempts are not universally successful.

The methods of disinfection used in private homes are generally inadequate. Andrewes states that "stools should be thoroughly mixed with the disinfecting solution until no visible lumps remain and allowed to stand for three hours before being emptied into the sewer."¹⁵

In one of the large hospitals of Boston all the stools and urine from cases of infectious diseases are thoroughly mixed with a disinfecting solution and boiled before being discharged into the sewer. Only by such thorough measures can the infectious nature of the dejecta be destroyed.

Pollution of Harbor Waters through Undisinfected Sewage Wastes. Of the tuberculosis patients reported in the City of New York during the year 1908, 17,338, or 80 per cent., were treated at home. It is not probable, except in isolated cases, that the urine or feces of these patients were disinfected. To some extent, however, the sputum was disinfected as the result of the recent educational campaign for the prevention of tuberculosis.

Unfortunately many persons have tuberculosis without being aware of the fact and eject bacilli unconsciously, no attempt being made to disinfect the sputum, urine or feces. Similarly, in typhoid fever, before the patient is ill enough to be in bed, the discharges become dangerous and are emptied into the sewers without disinfection. In 1908 there were treated 1,582 cases, or 52 per cent. of the total number reported, in

¹⁰ Report to London County Council, 1900.

¹¹ 24th Report of Local Government Board of England Oyster Culture, 1894.

¹² Journal of Infectious Diseases, 1904, I, p. 641.

¹³ Journal of Infectious Diseases, 1906, Suppl. No. 2.

¹⁴ Report British Royal Commission on Sewage Disposal 1902.

¹⁵ Lessons in Disinfection and Sterilization, Andrewes, 1907

hospitals, and it may be assumed that at the hospitals the discharges were sometimes well disinfected. The other 48 per cent. were treated at home, and with the difficulties and extra labor needed for the disinfection of the discharges, disinfection was practised either in a partial and perfunctory manner or not at all. Further, during convalescence, virulent typhoid bacilli may be discharged in the urine and feces and this condition may persist after the return to health of the individual.

In 1905 and 1906 it was pointed out by a number of German investigators that virulent typhoid bacilli could be carried in the intestinal and urinary tract of numerous healthy individuals. In 1907 Soper reported in the *Journal of the American Medical Association*¹ the now famous case of a household servant who had been the cause of 26 cases of typhoid fever, one of which resulted fatally.

Graham, Overlander and Dealy reported in the *Boston Medical and Surgical Journal*² that they had found in the discharges of 65 convalescent typhoid fever patients about to be released from the Boston City Hospital, active bacilli in 15 cases, or 23 per cent. of the whole number. It is probable that more typhoid germs are produced by bacillus carriers than by persons sick in bed. These bacillus producers add to the quantity of infectious material which the sewers discharge into the harbor.

Genito-Urinary Diseases. Besides the diseases mentioned in the foregoing paragraphs there are a large number of persons in New York afflicted with inflammations of the genito-urinary tract; 30,000 such cases yearly would be a low estimate. In such inflammations there is a chronic discharge of pus in the urine accompanied with the ordinary pyogenic bacteria, the streptococci and staphylococci, and also with the organisms which cause the specific venereal diseases. Almost all the people with these infections are up and about during the course of the disease, and the disinfection of the urine being accompanied with some trouble it is generally not attempted.

SECTION II

INFLUENCE OF THE POLLUTED HARBOR WATERS ON PUBLIC HEALTH THROUGH THE CONSUMPTION OF SHELLFISH

In New York State. In 1904³ there was invested in the fish industry in New York State the sum of \$10,621,616. The catch amounted to 277,649,747 pounds, having a sale value of \$6,230,558 and giving employment to 11,493 men.

The shellfish industry in New York amounted to 3,843,846 bushels, composed of oysters, clams, mussels, scallops and empty shells. These products brought \$4,310,819, or 69 per cent. of the total value of the fishing industry in this State.

¹ Vol. 48, p. 2019.

² Vol. CLX, p. 38.

³ Dept. Commerce and Labor, Statistics of Fish for the Middle Atlantic States.



Bathing in Lower New York Bay. Large numbers of people bathe in the waters of New York in the summer



A Bathing Beach in Upper New York Bay. Many people, especially children, use the polluted beaches near home for shore baths



The Shaded Areas Indicate the Principal Sources of Oysters

In 1908¹ there were produced 2,647,500 bushels of clams and oysters which brought a revenue to their owners of \$2,844,070.² For the same year, according to the report of the Bureau of Marine Fisheries,³ there were 1,794,077 bushels of clams and oysters sent to New York markets. The total value of the shellfish including seed oysters amounted to \$2,205,540.62.

Taking the figures of the Census Bureau the total value of the catch for 1908 was \$4,592,440. The value of the shellfish was \$2,844,070 or 60 per cent. of the total. The shellfish business was by far the most important branch of the industry.

*In New Jersey.*⁴ The amount of capital invested in the fish industry in New Jersey in 1904 was \$2,695,796, and the total value of the catch was \$3,385,415. The total amount of fish was 90,108,068 pounds. The shellfish industry amounted to 2,541,793 bushels valued at \$2,122,296, or 60 per cent. of the total. In 1908⁵ the total value was \$3,068,590, the shellfish amounting to 2,892,200 bushels valued at \$1,705,000, 55 per cent. of the total.

The shellfish industry of New York and New Jersey is of peculiar interest because of the great value of the industry in these two states and on account of the dissemination of disease by the handling and eating of sewage polluted shellfish.

Oysters and Clams from the Metropolitan Waters. By far the greater part of the shellfish industry, 95 per cent. in New York and New Jersey, consists of the oyster trade, and what is true of the ways in which oysters may produce disease is, to a lesser extent, true of other shellfish. Oysters only will be considered here.

In a report to the New York Bay Pollution Commission is the following statement:⁶ "The upper part of New York bay once supported oyster beds which extended from Staten Island to above Newburgh. Bedloes Island, now called Liberty Island, was known as Oyster Island, and two small reefs just south of it were called the Little Oyster Islands. The oysters occurred here naturally and were reckoned a considerable source of wealth. They were so plentiful that the public was allowed to gather them with little or no restriction, until to-day these extensive grounds have become exhausted."

Other natural oyster grounds exist on the Jersey Flats, Raritan and Princess bays, Jamaica bay, the mouth of the Shrewsbury, Arthur Kill, Newark bay, Eastchester and Pelham bays and in most other salt water estuaries in the metropolitan district.

¹ Dept. Commerce and Labor, Bureau of Census, Preliminary Report.

² Includes scallops.

³ Forest, Fish and Game Commission, New York, Bureau of Marine Fisheries.

⁴ Statistics Middle Atlantic States.

⁵ Bureau of Census, Preliminary Reports.

⁶ Soper, New York Bay Pollution Commission Report, March, 31, 1905.

Comparatively few oysters are now taken from the natural reefs, there having been gathered but 20,805 bushels in 1904 while 2,847,702 bushels were taken in the same year from private areas. These private areas are State land under water leased for a term of years at a nominal sum per acre. Such growth of the oyster business as has recently occurred has been mainly on the eastern end of Long Island.

Of the 1,794,077 bushels of shellfish received at the New York markets during 1908 747,127 bushels came from beds within the metropolitan district; 160,400 bushels came from within the limits of The City of New York. From the Raritan and Princess bays, south of Staten Island, came 33,200 bushels, and from Jamaica bay came 127,000 bushels.

According to estimates made by the New York Bureau of Marine Fisheries these 747,127 bushels had a value of \$965,000. This is 34 per cent. of the total value of the shellfish industry in New York for 1908.

The total value of the catch of the shellfish industry for New Jersey for 1908 was \$2,122,296.

The value of the clams and oysters produced in the New Jersey counties of the metropolitan district in 1908 were as given in Table VI.

TABLE VI
VALUE OF SHELLFISH PRODUCED IN THE METROPOLITAN DISTRICT

County	Clams	Oysters	Total
Bergen .....	.....	.....	.....
Hudson .....	.....	\$20,300	\$20,300
Middlesex	\$13,750	49,340	63,090
Monmouth	211,785	69,858	281,643
Union .....	.....	6,240	6,240
Total	\$225,535	\$145,738	\$371,273*

*Statistics of the fisheries of the Middle Atlantic States for 1904, Department of Commerce and Labor.

Thus the value of the shellfish produced in 1908 in the harbor waters of the metropolitan district amounted to

New York	\$965,600 84
New Jersey	371,273 00
A total of	<u>\$1,336,873 84</u>

This does not include the value of the shore properties, boats and implements invested in the business.

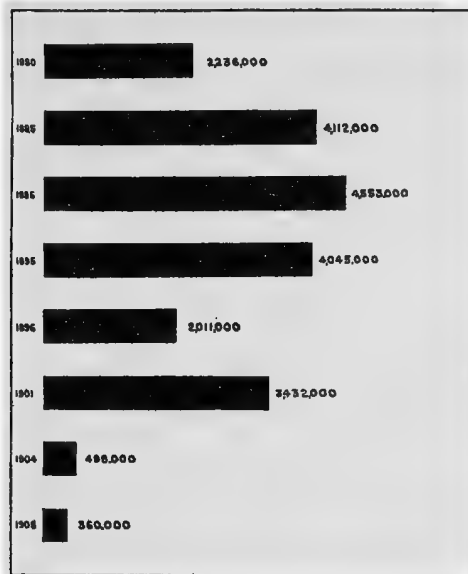
Some oysters and large numbers of clams are taken from natural grounds by individuals for their own consumption. The number of shellfish taken and the number of persons so engaged is not mentioned in any of the reports. These persons take clams and oysters from natural grounds apparently not under the surveillance of the Bureau of Marine Fisheries.

Oysters and Clams in Polluted Waters. The Bureau¹ of Marine Fisheries of New York State in its report for 1908 states "that it is now unlawful to place or allow to run into waters in the vicinity of oyster beds any sewage, sludge, acid or refuse, or any substance injurious to oyster culture, and upon it appearing that oyster beds have become polluted from one or more of these causes it becomes the duty of this Bureau to cause complaint to be made in a criminal action against the person or persons so offending. Such person is also liable in damages to the persons injured. It will at once be appreciated that the vast amount of sewage, said to be five hundred millions of gallons every 24 hours, emptied into our tidal waters by The City of New York is the most serious existing cause of pollution. In consequence of this situation, *no oysters for use as food are taken from New York bay, nor have any oysters for the markets been taken from these waters during the history of the Shellfisheries Department of the Forest, Fish and Game Commission.*" In spite of this official declaration, during 1908 and 1909 oysters were taken from natural beds off Robbins Reef. This was seen by members of the Metropolitan Sewerage Commission. Oysters in large numbers are still taken from the south shore of Staten Island in the Lower bay. The limits of New York bay in the report of the Bureau of Marine Fisheries are not defined; presumably the Upper bay only is meant. Nevertheless, the Bureau should be aware of the fact that oysters have been, until very recent years at least, not only grown in New York bay but drinked in that grossly polluted part of New York harbor known as the Kill van Kull and in the worse polluted waters of the Rahway river before being brought to the city markets.

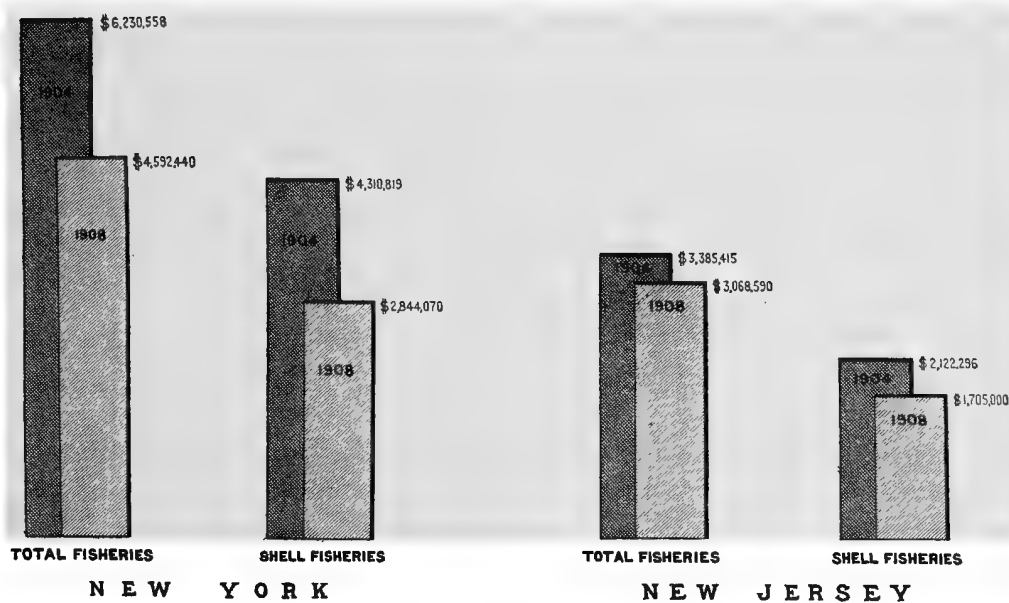
Soft clams abound along the shores of Jamaica bay, the waters of which have been shown to be sewage polluted. For the most part these soft clams are taken by various persons for their home use. In the summer, at low tide, dozens of people can be seen clam digging in Jamaica bay. It is obvious that many of the clams so taken may be given or sold to friends in the neighborhood. Soft clams are also taken in Newark bay, Arthur Kill, the Rahway river and off City Island and sold.

Hard clams are gathered just outside the Narrows near Sandy Hook and in the East river between Throgs Neck and Hell Gate.

¹ Report of Bureau of Marine Fisheries, 1908.



ANNUAL CATCH OF SHAD
IN POUNDS
NEW YORK



DECREASE IN VALUE OF
TOTAL CATCH OF FISH AND SHELL FISH

All of these regions have been shown to be polluted, although the Sandy Hook grounds are the cleanest.

THE SHAD FISHERIES

Value of the Catch. The shad fishing industry in the metropolitan district depends upon the annual migration of the shad, *clupea sapidissima*, from the sea up the Hudson river to spawn. This industry has been of considerable value to the counties of New York and New Jersey which have shores upon the Hudson river.

The stake gill net is used for catching shad, but owing to the alleged menace of the nets to navigation the Government has placed some restriction upon these operations. The value of the shad catch in New Jersey in 1904 was \$238,517 and in 1908 \$229,490. The amount of the catch in 1908 was 25 per cent. less than in 1904.

In New York there has also been a diminution in the amount and value of the shad catch. In the '80's and '90's the shad catch averaged from three to five million pounds; in 1901 it was 3,432,472; in 1904, 498,119, and in 1908, 359,900. In 1901 the value was \$110,682; in 1904, \$38,826, and in 1908, \$27,410. See Table VII.

TABLE VII
ANNUAL CATCH OF SHAD IN NEW YORK AND NEW JERSEY

Year	New York			New Jersey	
	Number of Fish	Weight in Pounds	Value	Weight in Pounds	Value
1880.....	639,000*	2,236,500†	\$136,680	749,997	\$35,000*
1885.....	1,174,835*	4,111,922†	.....	.....	.....
1886.....	1,200,949*	4,553,321†	.....	.....	.....
1895.....	1,155,610*	4,044,635†	.....	.....	.....
1896.....	588,898*	2,011,143†	83,237	11,684,480†	340,056*
1901.....	.....	3,432,472†	110,682†	13,993,233†	769,450†
1904.....	.....	498,119‡	38,826‡	4,337,907‡	238,517‡
1908.....	.....	359,900§	27,410§	3,004,200	229,490§

* Figures given by C. H. Stevenson, U. S. Fish Commission Report, 1898.

† Number of fish times average weight 3½ lbs. (Stevenson's figures.)

‡ Statistics of Fisheries of the Middle Atlantic States, 1904.

§ Preliminary Reports, Bureau of Census, Department of Commerce and Labor, 1908.

The shad catch in the counties of The City of New York in 1901 and 1904 was as given in Table VIII.

TABLE VIII
CATCH OF SHAD BY COUNTIES OF THE CITY OF NEW YORK

	1901 Pounds	1904 Pounds	1901 Value	1904 Value
New York County.....	5,600	2,840	\$250	\$280
Kings County	45,975	17,260	2,715	1,384
Richmond County.....	118,700	62,840	6,360	5,051
	170,275	82,940	\$9,325	\$6,715

* Fisheries Middle Atlantic States, 1904, Dept. Commerce and Labor.

The value and amount of the shad catch in the counties of New York State was as given in Table IX.

TABLE IX
CATCH OF SHAD BY COUNTIES IN NEW YORK STATE IN 1904

1904	Pounds	Value
Albany.....	296	\$29
Columbia.....	21,194	1,595
Dutchess.....	140,843	9,835
Greene.....	6,400	440
Kings.....	17,260	1,384
New York.....	2,840	280
Orange.....	21,844	1,538
Putnam.....	1,500	110
Rensselaer.....	1,712	135
Richmond.....	62,840	5,051
Rockland.....	30,794	2,434
Suffolk.....	12,684	1,235
Ulster.....	109,842	7,738
Westchester.....	68,070	5,042
Total.....	498,119	\$36,846

The New Jersey catch is given because about 15 per cent. of the catch is obtained in Hudson and Bergen counties from the Hudson river. About two-thirds of the

catch for 1904 in Bergen County was taken by men from Monmouth and Ocean counties, who move up on the Hudson during the shad season.

TABLE X
CATCH OF SHAD BY COUNTIES IN NEW JERSEY IN 1904

	Pounds	Value
Hudson County.....	69,200	\$8,860
Bergen County.....	201,800	17,758
Total.....	271,000	\$26,618

From the table referring to the shad catch it is readily observed that although an important industry, its total value in the Hudson river in 1908, \$63,444, is comparatively small compared to the value of the oyster industry.

Writers on the subject, and official statements, speak of the variability of the size of the catch, but it is to be noted that although there has been a very marked diminution in the total number of fish caught this has been more noticeable in the Hudson than in the Delaware river. This is no doubt due, among other causes, to government restriction of the use of the stake gill net, natural decrease in the number of fish, the number caught in other rivers being kept up by the shad hatcheries of the United States Government, and to sewage pollution of the waters.

Even if the latter cause be not an important one, it is commonly considered that Hudson river shad is far less palatable than formerly and less palatable than shad caught in waters further south.

Effect of the Harbor Waters Upon Fish Life. Mr. Charles H. Townsend, Director of the New York City Aquarium of the New York Zoological Society, was asked to answer a number of questions which would bear on the effect of the harbor waters on fish life. The questions and the replies, which Mr. Townsend gives permission to publish, are as follows:

Question. What, in general, is your opinion of the effect of the waters of New York harbor upon fishes which normally live in them?

Answer. My opinion is that the water imparts an unpleasant flavor to shad passing up the river. It tends to reduce the kinds and numbers of brackish-water forms of life which ought naturally to be found there, and which must have been more abundant fifty years ago when the waters were clean just as they are still abundant in clean brackish-water in other bays. As a collecting ground for brackish-water forms for an aquarium the locality is a poor one and the only reason is the polluted water.



Gathering Driftwood for Fuel at the Battery, Manhattan. Driftwood sometimes coated an inch thick with grease and other material from the sewage-polluted harbor is taken into many homes daily



Fishermen Gathering Oysters at Robbins Reef in Upper New York Bay. Oysters and other shellfish are frequently gathered at places which are heavily polluted with sewage

Question. What effect has the water upon fishes which do not normally live in it; such effects as you would see upon deep-sea or other fishes brought from a distance to the Aquarium?

Answer. When collections of fishes from the outside coasts were kept in water pumped from the harbor, constant restocking of the tanks was necessary to keep up the marine exhibits of the Aquarium. Since the new system of pure stored sea water became available a year and a half ago, the loss of specimens from impure water has been eliminated. Our losses are now no greater than those occurring in other public aquariums, being limited to "natural causes."

Question. Would you be willing to express an opinion that the diminution of shad, crabs, oysters, etc., in the harbor had any relation to sewage pollution, or pollution by trade wastes?

Answer. I am certain that many kinds of fishes and crustaceans, formerly abundant near the city and now no longer common there, have been dispersed by sewage and trade wastes. I have no opinion as to the effects upon oysters under such conditions, but should unhesitatingly condemn the practice of keeping them in waters affected in any degree by sewage.

UNCOOKED OYSTERS AND TYPHOID FEVER

As early as 1879 oysters were considered a cause of typhoid fever and gastro-intestinal disorders. Cammeron,¹ in 1880, read a paper before the British Medical Association entitled, "Oysters and Typhoid," in which he suggested that contaminated oysters might be the cause of outbreaks of typhoid fever and cholera. This was suggested again in England in 1893 by Thorne-Thorne² and in 1894 was published a report by Conn³ on an outbreak of typhoid fever at Wesleyan University. As this report is of much importance in showing the relation between shellfish and disease a short description of this epidemic is given.

Wesleyan University Epidemic. There were 25 cases of fever, 23 of which were pronounced typhoid. The condition of the water was first investigated and it was found that the students affected had drunk the same water that others in the town had taken with no ill effects. Similarly ice, milk and ice cream were all found to be used by others than the students diseased. It was found that of the 23 students all belonged to three different fraternities, that about three weeks previous to the onset of the illness these three fraternities had had a banquet. It was also found that of five Yale students who had attended this banquet two had developed typhoid fever.

There were no other cases of typhoid fever in the town so it became evident that there must have been one single, common cause of infection. The other articles of diet used at the banquet were investigated (celery, lettuce, chicken, lobster, ham and other articles), but it was found that these were procured by the three different fraternities at

¹ British Medical Journal, 1880, Vol. II, p. 471.

² 24th Report, Local Government Board for England.

³ Medical Record, 1894, Vol. 46 p. 743.

different places. Four fraternities had had suppers the same night and all had received oysters from the same source. One fraternity had used them cooked and no case of typhoid had developed in this fraternity. The other three fraternities ate the oysters raw. All of the students who fell sick ate raw oysters.

It was found that the oysters were shipped from Fairhaven, Connecticut. The oysters were taken from deep water in Long Island Sound and had been allowed to "drink" in the brackish water of the Quinnipiac river for "fattening," *i. e.*, bloating, before being sent to the consumer. Close to the oyster beds where the fattening occurred was the outlet of a private sewer, 300 feet from the beds. In a private house which drained into this sewer were two severe cases of typhoid fever. These two cases were critically ill during the time that the oysters were "drinking" in the river. It was then found by Foote,¹ of New Haven, that the bacillus typhosus would live in oysters for at least 48 hours.

Since this report by Conn a number of other epidemics have been reported where the chain of evidence seemed positive that typhoid fever resulted from the eating of oysters and other shellfish. Chantemesse,² in Paris, 1896; Plowwright,³ in 1900; Thresh,⁴ in 1902. Two epidemics in Winchester and Southampton, England, were investigated by Bulstrode⁵ in 1903.

Investigations by the Local Government Board. An investigation was made under the direction of the Local Government Board of England by Bulstrode and Klein,⁶ the results of which have been summarized by Thorne-Thorne as follows: "First, The cholera vibrio, and still more, the typhoid bacillus are difficult of demonstration in sewage known to have received them. Second, Both these organisms may persist in sea water tanks for two or more weeks, the typhoid bacillus retaining its characteristics unimpaired, whilst the cholera vibrio tends to lose them. Third, Oysters from sources which appeared to be free from risk of sewage contamination exhibited none of the bacteria, specific or otherwise, which are commonly regarded as being concerned with sewage. Fourth, Oysters from a few out of numerous batches derived from sources where they did appear to be exposed to risk of sewage contamination were found to exhibit colon bacilli; a circumstance which, notwithstanding the comparative universality of this intestinal organism, may be regarded as having some significance by reason of the absence of this bacillus from oysters which appeared to have been exposed to no such risk. Fifth, in one case, where the circumstances were especially

¹ Medical News, 1895, Vol. 66, p. 320.

² Bulletin de l'Académie de Médecine, 1896, p. 534.

³ British Medical Journal, 1900, Vol. II, p. 681.

⁴ Lancet, 1902, p. 1567.

⁵ Special Report Local Government Board, England, May 1903.

⁶ Report (24th) Local Government Board, England, 1894.

suspicious, Eberth's typhoid bacillus was found in the mingled body and liquor of the oyster."

This report was published in 1894. Since that time there has been little change of opinion though a mass of information on this subject has been acquired by the Royal Commission on Sewage Disposal of Great Britain.¹

Southend-on-Sea and Yare. In reports to this British Commission Marsh¹ reported that of 105 cases of typhoid fever in Southend-on-Sea at least 50 per cent. were due to the consumption of shellfish contaminated by sewage. He further reported that in the town of Yare where typhoid was endemic the cases diminished in number 30 per cent. in 1901, after the sale of mussels had been prohibited.

Brighton. A. Newsholme¹ reported that of the 643 cases of typhoid fever in Brighton from 1894 to 1902, 37 per cent. were ascribed to shellfish. The shellfish were traced to particular layings which were proved to be exposed to sewage contamination and typhoid fever was found to exist among the population draining to the vicinity of the layings.

Manchester. Niven¹ also reported that a number of the cases of typhoid fever in Manchester were also ascribable to shellfish.

London. Shirley Murphy¹ thought that at least eight per cent. of the cases of typhoid fever in London in 1902 were due to the eating of shellfish.

*Conclusions of the Royal Commission on Sewage Disposal*²—"After carefully considering the whole of the evidence on this point, we are satisfied that a considerable number of cases of enteric fever and other illness are caused by the consumption of shellfish which have been exposed to sewage contamination; but in the present state of knowledge, we do not think it possible to make an accurate numerical statement.

"Moreover, an examination of the figures which have been placed before us as regards those towns in which the subject has been most carefully studied shows that there may be occasional errors. Indeed, the witnesses themselves recognized that absolutely accurate figures are not obtainable.

"We are far from denying that isolated cases may have been due to contaminated shellfish, but we must remember that the possibility of some of them being due to other causes cannot be altogether excluded."

Considerable work of importance has also been done in this country since the first report by Conn in 1894.

New York Harbor. Soper, in the report of the New York Bay Pollution Commission,³ states that Jackson working for the Commission, found the colon bacillus in samples of oysters from Gravesend bay, off Elm Tree Beacon, Swash channel, Great Kills and Princess bay. Samples were also examined by the Bender Hygienic Labora-

¹ Report of the Royal Commission on Sewage Disposal, Vol. I, II, III, 1904.

² British Royal Commission on Sewage Disposal, Vol. I, p. 29, 1904.

³ Report, 1905, p. 56.

tory at Albany and 33 per cent. of the Gravesend bay oysters contained colon bacilli as did 80 per cent. of the oysters taken off Elm Tree Beacon.

Samples of oysters taken from the Upper and Lower bays showed evidence of fecal contamination.

Lawrence, L. I. During the same year (1905) Soper¹ reported the results of his investigation as to the cause of a typhoid fever epidemic at Lawrence, L. I.

In this investigation it was found that 21 out of the 31 cases of typhoid fever which had occurred in the epidemic were the result of eating oysters contaminated with sewage. In some cases typhoid was produced by handling the polluted shells.

It was found that most of the oysters were taken from layings in Grass Hassock channel, itself polluted by the entire sewage of Arverne, a summer city of 15,000 inhabitants. Oysters from these beds were eaten by most of those persons who subsequently contracted typhoid fever.

It was also found that some other oysters which produced typhoid had been placed in floats in an arm of Jamaica bay near Inwood at a point where the bay received the effluent from the Far Rockaway sewage disposal works. Analyses proved that the effluent from these works contained a greater number of bacteria than the raw sewage. The water about the oyster floats was found to contain colon bacilli to the extent of at least one of these germs to each 0.1 c. c. of the water. Oysters from Grass Hassock channel and from the floats at Inwood in 25 per cent. of the samples examined showed colon bacilli in 0.1 c. c. of the shell water and in 60 per cent. of samples in 1.0 c. c. of the shell water.

Narragansett Bay. Caleb Fuller,² in a report on the contamination of oysters of Narragansett bay, made bacteriological analyses of a large number of samples of water taken from oyster beds and also made similar analyses of 200 oysters.

Fuller found that the water for five miles below the outlet of the Providence sewer outfalls contained colon bacilli, and that the waters of Providence river and Narragansett bay, eight miles or more distant from the principal sewers that discharge into these waters, contain sewage matters or colon bacilli.

One hundred oysters were taken from layings widely removed from any possible source of sewage contamination and were examined with the idea of determining the normal bacteria in the oyster. In none of these samples was the colon bacillus found. This agrees with the reports of the British Royal Commission that the colon bacillus is not normally found in the shell water or the intestine of oysters.

¹ Medical News, February 11, 1905.

² The Distribution of Sewage in the Waters of Narragansett Bay, with especial reference to the contamination of the oyster beds. Bulletin No. 569, Bureau of Fisheries, Department of Commerce and Labor, 1905.

In the 200 oysters examined, Fuller found bacillus coli in oysters taken from beds that were six and a half miles from the source of pollution. Fuller concludes that in those waters there is a distinct relation between the bacillus coli in the water and in the shellfish living in those waters.

“When bacillus coli is entirely absent from the water it can not be found in the shellfish, but when the surrounding waters are infected with it it is almost certain to be found in the shellfish.

“Examination of the shellfish from the lower river and bay demonstrate that the bacteria usually occurring in oysters taken from uncontaminated waters are such forms as are commonly found in water.

“No organisms of the colon group were isolated from these oysters.”

Investigations of New York State Department of Health. During the summer of 1908 an investigation was made by the New York State Department of Health of the sanitary condition of the shellfish grounds in this State. The report made by the Department also goes into the relation between sewage-contaminated oysters and disease, and gives a review of the work done in this direction.

An important feature of the investigation was the sanitary inspection and bacteriological examination of the leased and private oyster grounds in the State. Of the oyster grounds within the metropolitan district, the Jamaica bay, Princess bay, Eastchester and Pelham bay and Raritan bay districts were investigated.

The data collected describe the public and private sewer outlets, the overflow pipes from cesspools and the outside privies located near the banks of streams and bays. The location of all leased oyster beds was noted on maps on which were also charted the location of sewer outlets, cesspools, etc. Bacteriological examinations were made of both oysters and water which were examined at the State Hygienic Laboratory.

The results of these examinations were tabulated and show that oysters taken from Jamaica from the following beds, Flatlands bay, Big channel, near Richardson and trestle, Ruffle bay, Big Fishkill channel, Pumpkin Patch channel, Goosekill creek, Raunt, Big channel (Old Swale marsh) Island, all showed sewage pollution, according to standards used by the Massachusetts State Board of Health (that is, the presence of colon bacilli in 1 c. c. volume of shell water in 50 per cent. of samples).

The sanitary survey made showed that many oyster beds were obviously polluted by public and private sewers and private cesspools and privies. The bacteriological examinations showed that water and oysters taken from these oyster beds contained evidence of sewage pollution.

SECTION III

INFLUENCE OF THE POLLUTED WATERS ON PUBLIC HEALTH THROUGH
BATHING

BATHING ESTABLISHMENTS AND BATHING BEACHES

Floating Bathing Establishments. The free floating bathing establishments, of which there were 12 during the summer of 1909, are constructed of wood. They are rectangular in plan, from 30 to 40 feet wide and 80 to 100 feet long. They have an uncovered swimming pool in the centre; around the sides are rows of small dressing rooms, with a narrow platform in front bordering upon the pool. Below the dressing compartments are floats which give the structure buoyancy. Around the outside, planks and slats project below the surface of the water to a distance of six or eight feet to keep out large floating debris. The floor of the pool is made of wood and is sufficiently open to allow the water to flow freely in and out.

A few days each week the bathing establishments are reserved for female bathers, the remaining days being reserved for males. During the summer there is great demand for the bathing accommodations, but only as many bathers are allowed in at a time as can be comfortably accommodated. It is a common sight on a warm day to see hundreds of boys, waiting their turn, held in check by policemen.

The bath is undoubtedly enjoyable to these boys and young men. Swimming is common and on the first plunge the mouths of many are filled with water. Diving, though prohibited, is frequent. Boys below puberty go into the baths nude; older boys and men wear trunks. Women wear bathing suits.

The floating bathing establishments are situated with but one exception either adjacent to Manhattan or in the East river, moored to docks made available for this purpose. The baths are used from about the first of July to the first week in October.

In 1908, during a season of 102 days, there were taken 1,479,025 baths by males and 934,936 by females, a total of 2,413,961. The average was 1,067 baths daily. No records are kept of the identity of the bathers.

Besides these free public bathing houses there were several private bath houses and bathing beaches open to the general public during the summer of 1909.

Inland Bathing Establishments. In addition to the floating bathing establishments there are 11 so-called interior bath houses in the Borough of Manhattan. Of these the Cherry and Oliver street bath was opened November 15 and the Rutgers place bath on December 28, 1909. In East Fifty-fourth street a bathing establishment

will be opened during 1910. There is one interior bathing establishment in the Borough of The Bronx and there are eight in the Borough of Brooklyn.

These interior bathing establishments have been erected to provide opportunities for free bathing. They are arranged with tubs and showers for both men and women. Towels and soap are not furnished because the loss of towels was found, upon experiment, to be very great, and there was a constant danger of infection from their use; soap was found to be wastefully used when given free.

The interior public bath houses are of much more value to the public than the floating bathing establishments because, for one reason, they are open daily throughout the year for men, women and children. They are both cleansing and wholesome and there is no danger of the transmission of disease.

The newer interior baths have been built in localities where the population is densest and in neighborhoods where the floating bathing establishments would necessarily have to be placed in harbor waters more or less intensely polluted.

In the year 1908 there were 7,907,230 baths taken in the public interior bath houses in the City of New York. Of this number 5,271,422 were taken in Manhattan, 2,405,890 in Brooklyn, and 239,918 in The Bronx. In the latter borough the figures include baths taken from May 17th only, the date of opening, to December 11, 1909.

In the same year there were also taken, in private interior bathing establishments, 64,502 baths at the Riverside House, 55,367 at Center Market place, 201,290 at the Milbank Memorial bath and 37,012 at the Demilt Dispensary.

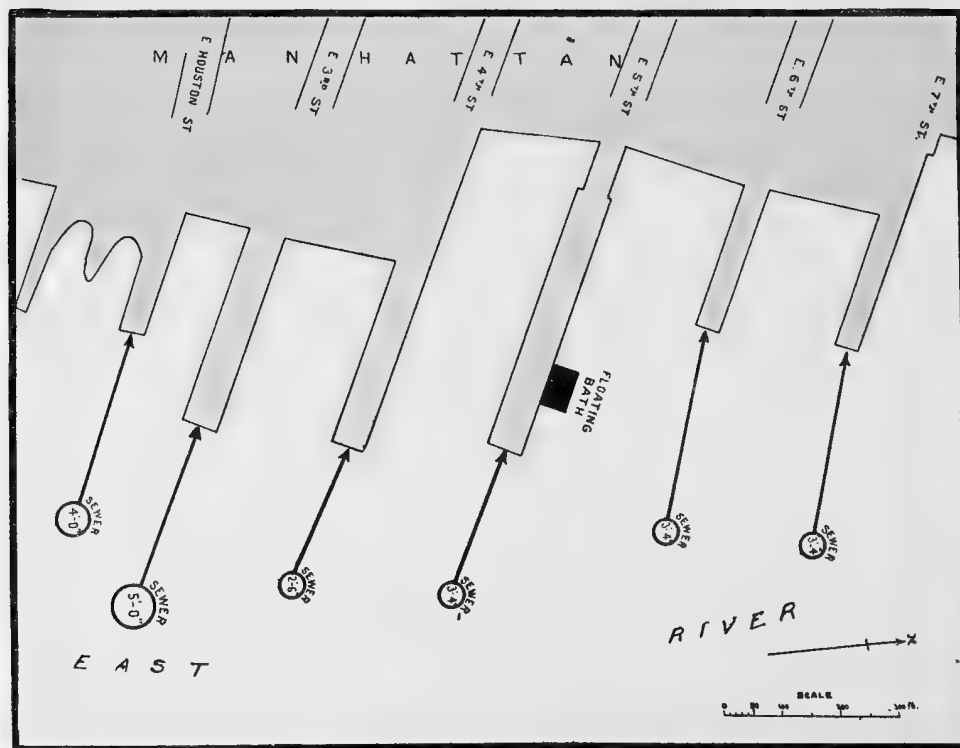
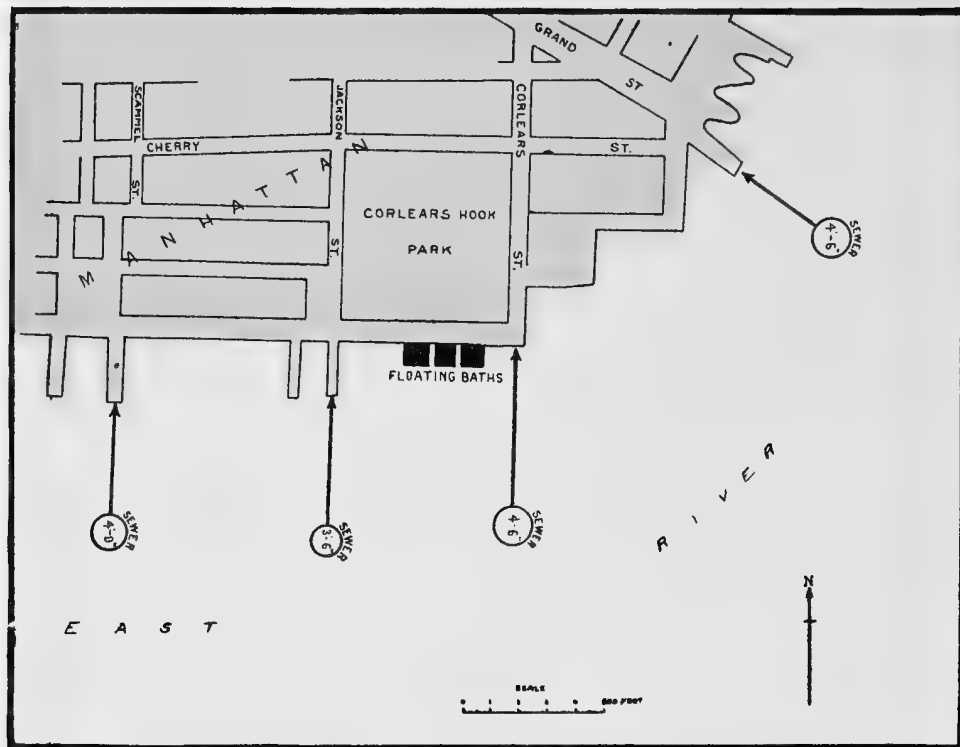
Location of the Floating Bathing Establishments. To secure a site for a free floating bathing establishment application is made by the Department of Public Works to the Department of Docks and Ferries which designates the docks available for the purpose. The site is not finally decided upon, however, until after an inspection is made by the Department of Health which has authority to refuse permits to the site.

There is a State law which has some bearing on this subject. It reads:¹

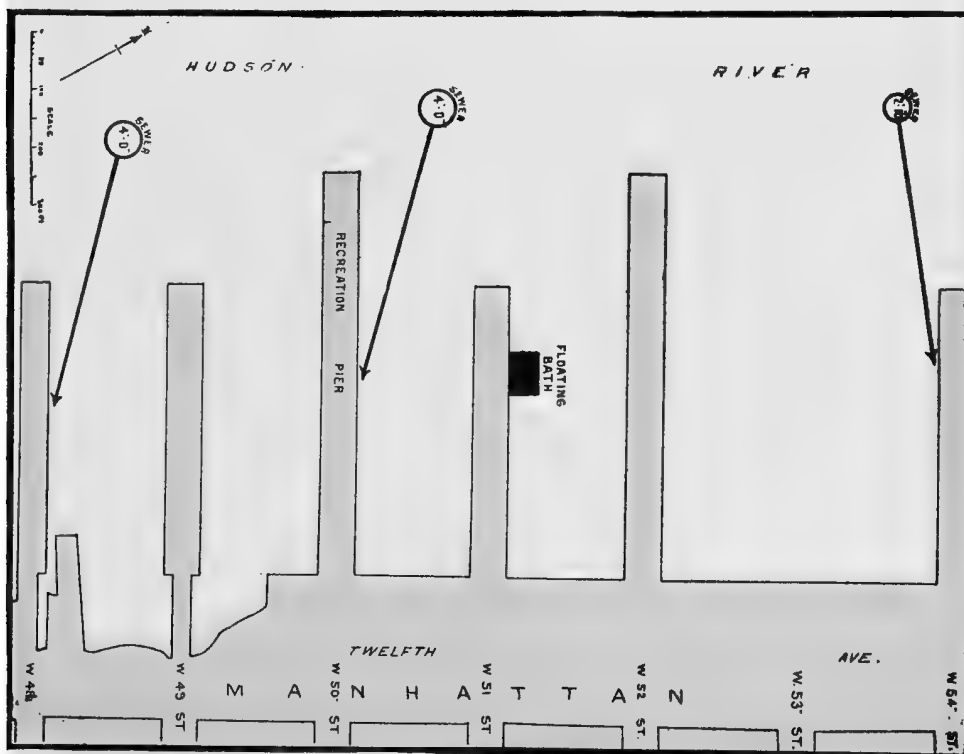
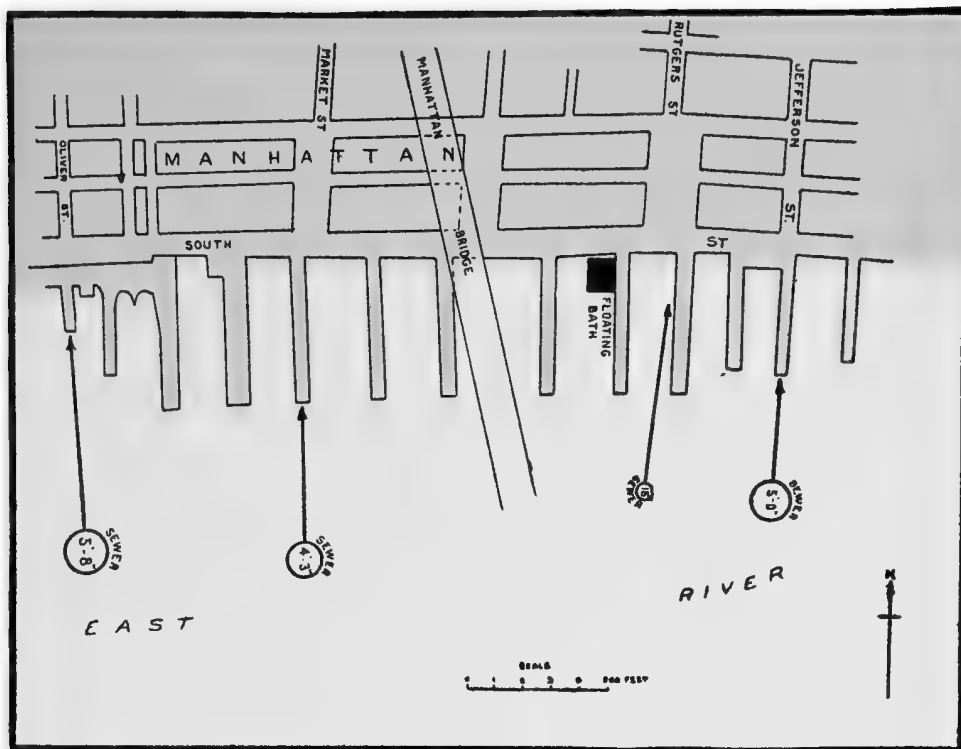
“Regulating the Sanitary Condition of Bathing Establishments and the Preservation of Life at Bathing Places. It shall be unlawful for any person to maintain, either as owner or lessee, any bathing establishment of any kind, in this state, for the accommodation of persons, for pay, or any consideration, at a point less than five hundred feet from any sewer connection emptying therein or thereat, so as to pollute, in any way, the waters used by those using or hiring bathing houses at such bathing establishments; it shall be the duty of such owner or lessee to provide separate toilet rooms, with waterclosets properly provided with sanitary plumbing, constructed in a manner approved by the local board of health and in such a way as not to contaminate the waters used by the bathers; it shall be the duty of such owner or lessee to thoroughly wash and disinfect or cause to be thoroughly washed and disinfected,

¹ Chapter 454, Laws of New York, 1905, (Extract).

DATA COLLECTED

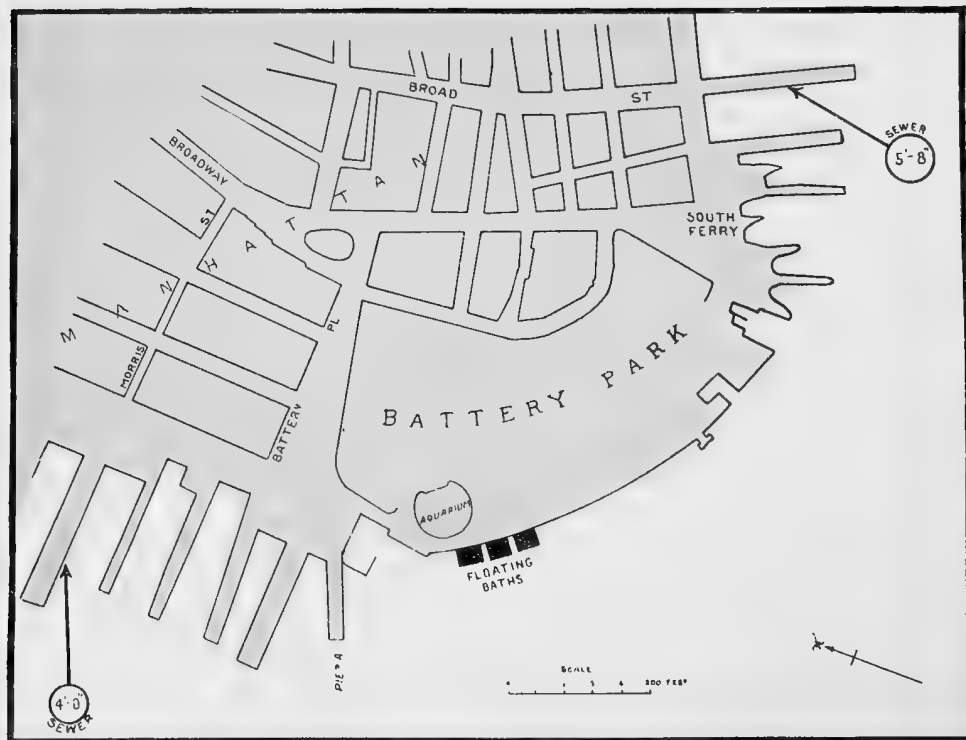
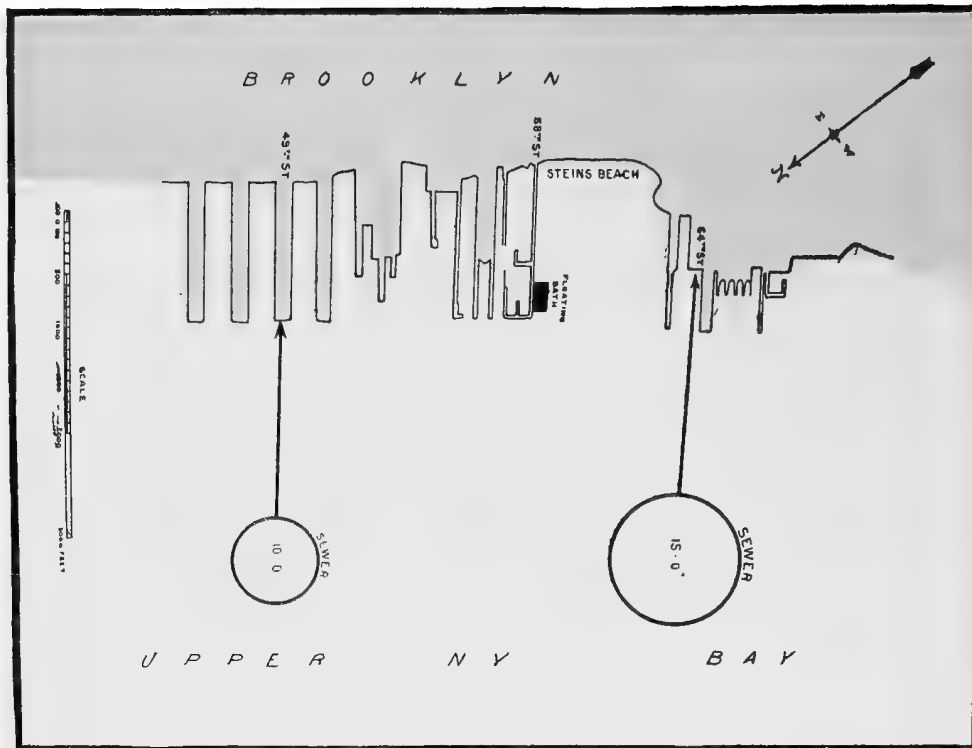


Floating Bathing Establishments in Relation to Sewer Outfalls



Floating Bathing Establishments in Relation to Sewer Outfalls

DATA COLLECTED



Floating Bathing Establishments in Relation to Sewer Outfalls

in a manner approved by the local board of health, all bathing suits that have been hired or used, before rehiring or permitting the use of the same again."

This law, although prohibiting the establishment of a floating bath or bathing place does not apply to free floating baths or free bathing beaches. It is also qualified by the statement "so as not to contaminate the waters used by the bathers."

These regulations show that legislative precautions were taken, though whether the law was intended to overlook free floating bathing establishments and bathing beaches is not known.

The outer sides of the bathing establishments, which project as a rule from six to eight feet below water, are usually made of slats several inches apart. These have been found inadequate to keep out floating debris and the larger particles of sewage with which the harbor waters abound. In some of the establishments boards have been nailed close together (in one sand bags have been piled up) to keep out the larger particles, and in many a small net on a pole, similar to a crab net, is kept to remove feces when they become too numerous.

The sewer outlets of Manhattan are so near together that it hardly seems possible to pick out locations for floating bathing establishments free from danger of intense sewage contamination.

The free floating bathing establishments were moored during the summer of 1909 in the situations given in Table XI.

TABLE XI

TABLE SHOWING LOCATION OF FLOATING BATHING ESTABLISHMENTS IN RELATION TO SEWER OUTLETS

Location of Bathing Establishment	Nearest Sewer Outlet	Size of Sewer	Distance of Sewer from Bathing Establishment
East river—			
Rutgers street.	Jefferson street.	5'	662.5 feet north.
	Rutgers street.	15"	225 feet north.
	Market street.	4' 3"	1,062.4 feet south.
	Oliver street.	5' 8"	1,875 feet south.
Corlears Park.	There were three floating bathing establishments in the summer of 1909 situated at Corlears Park.		
	Corlears street.	4' 6"	Egan's private bath, 100 feet north; free floating bath, 212.5 feet north; private salt bath, 312.5 feet north.
	Jackson street.	3' 6"	Egan's private bath, 462.5 feet north; free floating bath, 375 feet north; private salt bath, 275 feet north.

TABLE XI—*Continued*

Location of Bathing Establishment	Nearest Sewer Outlet	Size of Sewer	Distance of Sewer from Bathing Establishment
East 5th street. . . .	East Houston street . . .	4'	700 feet south.
	East 3d street.	5'	576.4 feet south.
	East 4th street.	2' 6"	323.5 feet south.
	East 5th street.	3' 4"	94.1 feet east.
	East 6th street.	3' 4"	229.4 feet northwest.
	East 7th street.	3' 4"	453 feet north-northwest.
	This establishment was situated within 500 feet of four sewer outlets.		
East 51st street. . . .	At East 51st street a free floating bathing establishment was maintained in 1908 but not in 1909.		
	It is interesting to note that a new bathing establishment supplied from the city drinking water supply is (1909) nearly completed in 54th street between 1st and 2d avenues, where a cleansing bath may be obtained without danger of pollution from sewage.		
East 96th street. . . .	East 95th street.	4'	323.5 feet south.
	East 100th street.	2' 10"	1,029.4 feet north.
Hudson river—			
Battery Baths	There were three floating bathing establishments at the Battery.		
	Morris street.	4'	1,400 feet northwest.
	Broad street.	5' 8"	2,100 feet southeast.
West 51st street. . . .	West 50th street.	2' 10"	252.9 feet south.
	West 54th street.	4'	670.5 feet north.
West 83d street. . . .	West 80th street.	5' 3"	764.7 feet south.
	West 91st street.	4'	2,200 feet north.
West 84th street. . . .	West 80th street.	5' 3"	970.5 feet south.
	West 91st street.	4'	2,000 feet north.
West 97th street. . . .	West 96th street.	6'	323.5 feet south.
	West 108th street.	4'	3,000 feet north.
West 135th street. . .	West 130th street.	7' 8"	1,558.8 feet south.
	West 138th street.	4'	300 feet north.
Brooklyn—			
58th street.	64th street.	15'	1,400 feet south.
	49th street.	10'	2,399.9 feet north.
Stein's Beach.	64th street.	15'	1,500 feet south.
	49th street.	10'	4,000 feet north and west.
Noble street.	Quay street.	5' 6"	788 feet south.
	Greenpoint avenue. . . .	2'	517 feet north.
Dock street.	Fulton street.	6'	882 feet southwest.
	Main street.	3'	488 feet west.

CONTAMINATION OF WATER OF BATHING ESTABLISHMENTS

A number of experiments were made in order to learn, by the use of strong dyes discharged into sewers, whether water polluted with sewage could be traced directly from a sewer outlet to the waters within the bathing establishments. Thirty-two experiments were made covering conditions at 14 bathing establishments. The dye was introduced into the water at a sewer outlet when the current was flowing from the sewer toward the bathing place. At six bathing establishments the water inside the establishment became colored with the dye within a few minutes and in two other cases the dye was seen staining the water on the outside. The dyes used were uranine and special scarlet.

The following description shows the character of the information collected in the experiments:

July 9, 1909. Weather fair; tidal current running strongly up stream; wind southwest. Low water at Governors Island at 7.58 A. M.

10.45 A. M. Put one pound special scarlet in outlet of sewer on Eightieth street pier. Color flowed upstream at the rate of about half a mile per hour.

11.00 A. M. The color had reached the bathing establishment and surrounded it. The observer went inside.

11.01 A. M. The color was very strongly visible in the swimming pool. The boys bathing noticed it.

11.05 A. M. A policeman and bath house keeper went on the roof of the bath house to see where the color was coming from.

11.12 A. M. Observer left vicinity.

Addenda. The swimming pool, on inspection before the arrival of the color contained bits of floating sewage, but no large pieces of feces were visible.

This establishment is 764 feet from the sewer outlet. The color reached it from the sewer outlet in 16 minutes. The inference was irresistible that sewage discharged from the West Eightieth street sewer during the flood current would pollute the water in the West Eighty-third street bathing establishment. This pollution would probably last through the entire duration of this current.

TABLE XII
EXPERIMENTS ON THE POLLUTION OF WATER IN FLOATING BATHING ESTABLISHMENTS.
MANHATTAN: HUDSON RIVER

No.	Date	Observers	Situation of Bath or Beach	Nearest Sewer Outlet	Sewer in Which Dye was Placed	Direction of Current	Direction of Bath from Sewer	Time	Inspection of Water Within Bathing Establishments		
									Feces	Sewage	Exp. Dye
1	Sept. 15, 1909	G. H. S...	Battery	Broad street..... Morris street.....	Broad street.....	South (slow)	{West and a} {little South}	11:45	0	0	0
2	Sept. 13, 1909	G. H. S...	Battery	Broad street..... Morris street.....	Morris street.....	South	South	3:15	..	..	0
3	Aug. 30, 1909	P. B. P...	West 51st street.....	West 50th street..... West 54th street.....	West 50th street.....	North	North	4:50	..	..	+
4	Aug. 31, 1909	R. N. H...	West 51st street.....	West 50th street..... West 54th street.....	West 54th street.....	South	South	4:22	..	..	0
5	Sept. 2, 1909	R. N. H...	West 51st street.....	West 50th street..... West 54th street.....	West 50th street.....	North	North	9:18	..	..	0
6	Sept. 7, 1909	G. H. S...	West 51st street.....	West 50th street..... West 54th street.....	West 50th street.....	North	North	11:54	0	+	+
7	Sept. 4, 1909	G. H. S...	West 83d street	West 80th street..... West — street.....	West 80th street.....	North	North	11:24	..	..	0
8	Sept. 7, 1909	G. H. S...	West 83d street	West 80th street..... West — street.....	West 80th street.....	North	North	10:45	0	+	+
9	Aug. 30, 1909	P. B. P...	West 83d street	West 80th street..... West — street.....	West 80th street.....	North	North	5:50	..	..	+
10	Sept. 9, 1909	G. H. S...	West 97th street.....	West 108th street..... West — street.....	West 108th street.....	South	South	11:23	..	..	* 0
11	Aug. 31, 1909	D. M., Jr.	West 137th street.....	West 138th street..... West 158th street.....	West 138th street.....	South	South	11:35	..	..	..
12	Aug. 31, 1909	R. N. H...	West 155th street*.....	West 158th street..... West — street.....	West 158th street.....	South	South	12:35	..	..	+
12	Aug. 31, 1909	R. N. H...	155th street bathing beach.....	West — street.....	West 158th street.....	South	South	12:35	..	..	+

* Private.

TABLE XII—Continued

MANHATTAN: EAST RIVER

No.	Date	Observers	Situation of Bath or Beach	Nearest Sewer Outlet	Sewer in Which Dye was Placed	Direction of Current	Direction of Bath from Sewer	Time	Inspection of Water Within Bathing Establishments		
									Feces	Sewage	Exp. Dye
13	Aug. 28, 1909	P. B. P.	Pier 33, between Pike and Rutgers streets	Rutgers street	Mouth Jefferson street	South	South	11:40	..	..	0
14	Aug. 28, 1909	P. B. P.	Pier 33, between Pike and Rutgers streets	Rutgers street	Rutgers street	South	South	11:55	+	+	+
15	Aug. 28, 1909	R. N. H.	*Corlears street, Egan's bath	Corlears street	Corlears street	Southwest	Southwest	10:52	+	+	** 0
16	Aug. 31, 1909	P. B. P.	*Egan's Bath	Jackson street	Corlears street	Southwest	Southwest	11:15	..	..	** 0
17	Aug. 31, 1909	P. B. P.	Adjacent free floating bath	Corlears street	Corlears street	Southwest	Southwest	11:15	+	+	** 0
18	Sept. 1, 1909	F. H. S.	Foot East 5th street	East 14th street	Mouth East 14th street	South	South	12:20	..	..	** 0
19	Sept. 14, 1909	F. H. S.	Foot East 5th street	East 3d street	Mouth East 14th street	South	South	2:13	..	..	0
20	Sept. 14, 1909	F. H. S.	Foot East 5th street	East 3d street	East 3d street	North	North	4:45	..	..	0
21	Aug. 31, 1909	R. N. H.	East 96th street bath	East 95th street	East 95th street	South	North	1:30	..	..	0
22	Sept. 9, 1909	G. H. S.	East 96th street bath	East 95th street	East 95th street	North	North	3:55	† +	+	+

* Private.

** Color about bath, but did not enter it.

† Possibly from bath privy.

DATA COLLECTED

TABLE XII—Continued

BROOKLYN

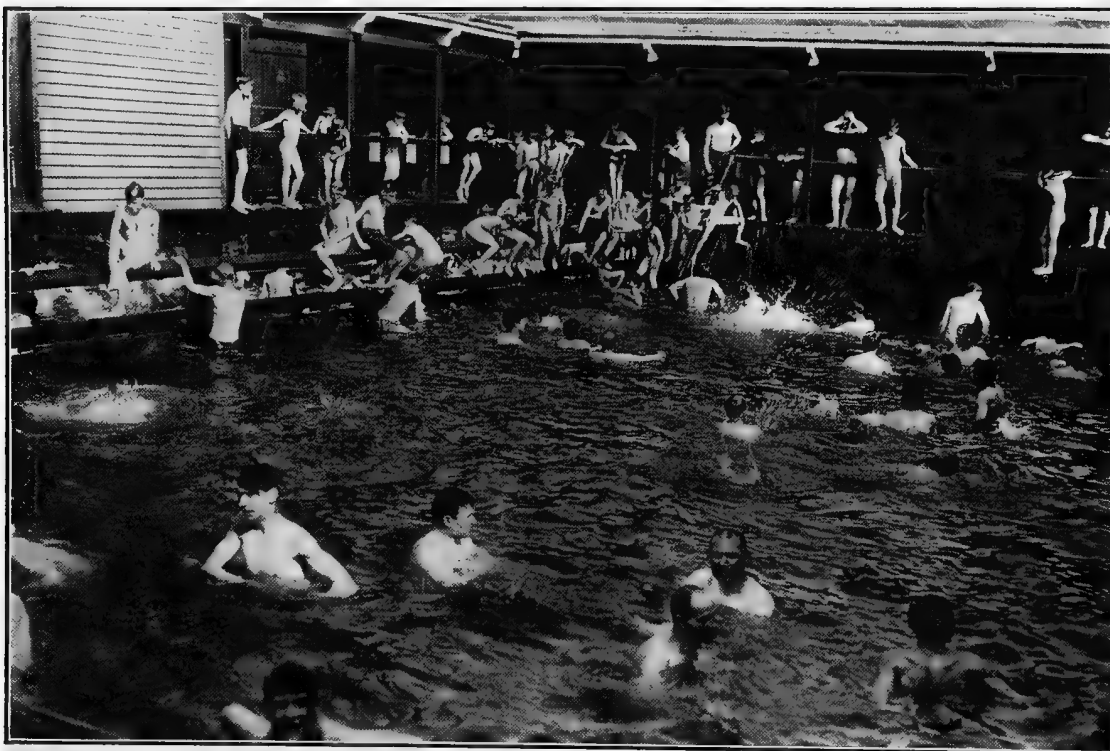
No.	Date.	Observers	Situation of Bath or Beach	Nearest Sewer Outlet	Sewer in Which Dye was Placed	Direction of Current	Direction Bath from Sewer	Time	Inspection of Water Within Bathing Establishments		
									Feces	Sewage	Exp. Dye
23	Aug. 27, 1909	P. B. P. . . .	58th street bath.	64th street.	64th street.	North.	North.	2 P.M.	..	..	* 0
24	Aug. 27, 1909	P. B. P. . . .	58th street bath.	64th street.	49th street.	South.	South.	11 A.M.	..	..	0
25	Aug. 27, 1909	P. B. P. . . .	Foot of Dock street.	Main street.	Main street.	South.	South.	10:30	..	..	+
26	Aug. 31, 1909	P. B. P. . . .	Foot of Dock street.	Main street.	Fulton street.	North.	North.	4:40	+	+	+
27	Aug. 12, 1909	P. B. P. . . .	Foot of Dock street.	Main street.	Fulton street.	North.	North.	11 A.M.	† ?	?	?
28	Aug. 28, 1909	J. P. F. . . .	Metropolitan, foot North 1st street.	Metropolitan avenue.	Metropolitan avenue.	South.	South.	1 P.M.	..	..	0
29	Aug. 31, 1909	J. P. F. . . .	Noble street bath.	Huron street.	Huron street.	South.	South.	12:21	..	..	0
30	Sept. 2, 1909	J. P. F. . . .	Noble street bath.	Huron street.	Huron street.	South.	South.	3:45	..	..	* ..
31	Aug. 12, 1909	J. P. F. . . .	Crescent Athletic Club.	79th street.	79th street.	South.	South.	10:39	Water off club pier contains feces, sewage and dye	Water off club pier contains feces, sewage and dye	0
32	Aug. 12, 1909	J. P. F. . . .	58th street.	64th street.	64th street.	South 12:58	North 2:35	..	..	..	* 0

* Color about bath, but did not enter it.

† Bath removed. Water at site of bath contained fecal matter, sewage and experimental dye.



Exterior of a Free Floating Bathing Establishment. It is impossible to locate bathing establishments at a safe distance from the sewer outlets



Interior of a Free Floating Bathing Establishment. Sewage particles were often visible in the water of these baths

DANGER OF BATHING IN THE HARBOR WATER

Typhoid Fever. It is well known that typhoid fever is frequently a water-borne disease, and it has been shown that less than one glass of water containing typhoid bacilli may cause typhoid fever. The discharges from a single patient have been known to pollute the entire water supply of a city sufficiently to cause a serious epidemic of typhoid fever. Other infectious diseases, such as pneumonia, meningitis, tuberculosis, and diphtheria, may be water-borne.

The water of the harbor, contaminated constantly by sewage, must contain typhoid bacilli, because typhoid is always present in the City of New York. It has been shown that these bacilli may live for months in water. Taking water into the mouth while swimming is common, and those who have bathed in this manner know that such water is not infrequently swallowed.

Diseases of the Eye. In public bathing establishments inflammations of the eye are not infrequently seen. These inflammations are usually of the nature of conjunctivitis, or pink-eye, a disease which must not, however, be confused with the redness of the eyes which so frequently follows bathing in salt water. This latter passes away in a few hours. With conjunctivitis, however, the eyes remain reddened and matter or pus is formed which persists for days, sometimes weeks, before a cure is effected. This disease is dangerous, for others may be infected. Serious loss of time may result on account of inability to use the eyes during the course of the disease. As a rule, the disease runs a short course and does not destroy the sight.

SECTION IV

FLIES, INSECTS, VERMIN AND OTHER AGENCIES AS CARRIERS OF DISEASE GERMS FROM THE POLLUTED HARBOR

FLIES AS CARRIERS OF DISEASE GERMS

During the last 30 years scientific experiments have shown that flies may act as carriers of the germs of disease. As early as 1869 Nysin¹ believed that anthrax was transmitted by flies, and Nuttall² in a review of the literature stated in 1900 "that ordinary flies (*musca domestica* and the like) may carry about and deposit the bacillus of anthrax in their excrements, or cause infection through their soiled exterior coming in contact with wounded surfaces * * *."

Nuttall also showed that plague bacilli could live 48 to 72 hours in flies. McCrae³ reported cases of cholera evidently transmitted by flies in 1894. Numerous other observations have been made on the life of the fly and the possibility of its carrying disease germs.

¹ Quoted by Nuttall.

² Johns Hopkins Hospital Reports, Vol. VIII, 1900, p. 1.

³ Quoted by Nuttall.

Flies multiply with marvellous rapidity. They develop usually in moist and decaying organic substances. Some observers state that they occasionally travel ten miles an hour; others believe that they rarely migrate more than 200 yards from where they are hatched.

*Jackson's Report.*¹ A report by D. D. Jackson consisted of a description of an inspection of the waterfront of the various boroughs of New York, particularly Manhattan, and a study of the prevalence and distribution of flies and cases of certain diseases in order to demonstrate what proportion of intestinal disorders in New York were contracted through the agency of flies.

The author describes existing conditions at the waterfront, noting in detail the filthy state of docks, their lack of water-closet facilities and the constant presence of fecal discharge upon them. The polluted condition of the water adjacent to the docks is also mentioned.

The prevalence of flies was noted by the number of flies caught in cages placed in four stations in Brooklyn, two in New York and one at City Island. The flies caught in these cages were counted. The greatest number was captured during the last two weeks of July and the first two weeks of August. The author found that the greatest number of deaths from intestinal diseases occurred during these weeks. He also discovered that the prevalence of flies, heat and deaths from intestinal diseases followed a similar curve. To make the incidence of typhoid fever agree with this curve the date of death was set back two months, allowing three weeks for incubation and five weeks for illness.

A careful study of the report leads to the opinion that the conclusions are not fully supported by the facts. Jackson believed that the typhoid cases and deaths from intestinal diseases all occurred at points located adjacent to the most polluted areas of waterfront. But close examination of his plotted chart of deaths from intestinal diseases in Manhattan shows that the number of deaths varied with the density of population. The deaths from cancer in 1903 showed the same relative distribution as typhoid, and it is not supposable that cancer is caused by flies. The distribution of cases of typhoid does not differ from the distribution of cases of any disease, and the greater number of deaths from intestinal diseases occur in the same areas as the deaths from any other disease.

OTHER AGENCIES IN THE SPREAD OF INFECTIOUS DISEASES

Rats and Vermin. It is a recognized fact that rats and mice suffer from certain communicable diseases which may also occur in man, notably the plague. It has

¹ Report to New York Merchants Association on an investigation of the relation of flies and the polluted waterfront of the City of New York to typhoid fever, by D. D. Jackson, 1908.

further been shown that these animals, especially rats, have carried plague bacilli from human beings and infected other human beings with this disease. No definite statements have been made, however, to show that typhoid fever and other intestinal diseases may be caused by rodents.

Other vermin as well as rodents exist along the waterfront and may act as carriers of infectious material.

Driftwood. Driftwood is constantly collecting along the shores, frequently in the midst of fields of sewage. The driftwood collects along the shores, more in some places than in others, and persons may be found daily gathering this wood. Persons have been seen picking driftwood out of the water in which inspectors of the Commission have seen fecal matter, garbage, vegetables, decomposing fruit, a pair of lungs, etc.

Favorite places for the collection of driftwood are the Battery, East Fifty-first street, West Eighty-third street, Nortons Point, the shores of Staten Island and various other points along the Harlem and Hudson rivers.

The collection of driftwood is another way in which infectious material may be carried from the waters to the people. The wood is carried to homes and sometimes handled by many persons before it is burned. Specimens of driftwood collected by the Metropolitan Sewage Commission have been examined by the City of New York Department of Health, and found to be heavily contaminated with fecal bacteria.

SECTION V

INFLUENCE OF ODORS ON HEALTH

The harbor waters are used by a large number of persons daily in moving on passenger boats from one part of the harbor to another. During the year 1903, thirteen ferry companies carried 194,161,515 passengers.

Odors in various parts of the harbor now exist and it is conceivable that in future they may be so aggravated as to become a nuisance and prevent the enjoyment heretofore afforded to excursionists.

Hospitals Along the Waterfront. For the sake of convenience of location and coolness a number of municipal hospitals are situated along the waterfront. A superintendent of one of these institutions states that the presence of sewage and fecal material in the waters had an unpleasant effect upon the patients. Although there may be no visible effect upon the public health, unpleasant effects are produced by the present condition of the harbor, which, if aggravated, may cause more serious effects on public health.

CHAPTER XII

LEGAL JURISDICTION OVER SEWAGE DISPOSAL IN THE METROPOLITAN DISTRICT OF NEW YORK

Sanitary jurisdiction is exercised by the United States Government, the States of New York and New Jersey, and the City of New York over the harbor of New York, although the regulations in force with regard to sewage disposal are by no means strict, and have no reference to the general condition of the waters. The principal object of the government regulations is to prevent the dumping of solid matters into the water to the injury of the channels; the main object of the regulation by the State of New York is the management of the quarantine, and the principal aim of the City's jurisdiction is to prevent local nuisances along the shores.

JURISDICTION BY THE UNITED STATES

The jurisdiction exercised by the United States Government is carried on through the Corps of Engineers of the War Department. There is a special bureau for this work in the New York district.

Origin of Government Control. In the year 1884 complaints of injury to the harbor from dumping solid refuse into it took definite shape and surveys were made by Commander H. C. Taylor, U. S. N., at the request of Mayor Edson of New York. These seemed to show a startling diminution in the depth of water at Sandy Hook. The reduction in depth was considered by experts who were called upon to investigate the matter to be due largely, if not wholly, to the dumping of solid refuse into the waters of the harbor and its tributaries. The question was inquired into by the Chamber of Commerce of the State of New York, which body in course of time expressed an opinion confirmatory of the reports. In the absence of adequate protective legislation by the State of New York and in view of a claim of jurisdiction by New Jersey over a portion of the bay, an appeal was made to the United States Government to assume exclusive control. The government was asked to assign a competent officer of the United States Engineer Corps to take charge of measures to prevent further injury to the channels by solid matter. As a result, an Act was passed by Congress and approved June 29, 1888, to prevent obstructive and injurious deposits in the harbor of New York and its adjacent waters by dumping or otherwise, and to prevent such offences. This act was amended in 1894 so as to enlarge the functions and powers of the office of Supervisor of the Harbor which had been created.

Power and Jurisdiction of the Supervisor of the Harbor. Under the provisions of the original act a line officer of the navy is designated to discharge the duties created by the act, this officer being under the direction of the Secretary of War. The Supervisor has power to prevent the pollution of the harbor, but only by material discharged in solid form, and is probably without jurisdiction over such wastes as may be discharged through sewers. Violation of the requirements is a misdemeanor punishable by fine of between \$250 and \$2,500 and imprisonment for from 30 days to one year, either or both, as the judge before whom conviction is obtained may decide. The work done by the Supervisor costs the national government about \$150,000 annually and is carried on chiefly by means of inspections, a number of steam vessels being employed for the purpose. An attempt is made to keep track of all the solid matter, amounting to upwards of 18,000,000 cubic yards per year, transported across the harbor. In spite of the utmost vigilance it has been impossible, so far, to prevent the premature discharge of cargoes on their way to the dumping grounds which the Supervisor has designated in the ocean beyond the harbor limits. When culprits are caught dumping their cargoes surreptitiously the excuse is generally given that it has been necessary to discharge the material because of stress of weather to save the scows and the lives of the crews. It is estimated by the Supervisor that about 6,000 cubic yards of solid material are accidentally or intentionally lost overboard annually. This quantity seems small when the quantities transported and the crude method of transfer are considered.

The Harbor Line Board and Suits Against New Jersey. Pollution by sewage is a matter over which the War Department has no control through the Harbor Line Board. This Board is composed of five officers of the Corps of Engineers of the United States Army each of whom has charge of the work which the United States Government is constantly doing to improve and maintain the harbor for the purposes of navigation.

The sanitary significance of sewage pollution in New York harbor is not a matter with which the Government has interested itself except in a suit brought by the State of New York against the Passaic Valley Sewerage Commissioners and the State of New Jersey to prevent the execution of the Passaic valley sewerage project and in a similar protest against the Bronx valley sewerage project. In the Passaic valley suit the United States Government joined with the State of New York in protesting before the United States Supreme Court. The basis of action by the United States was the supposed injury to government property situated in New York harbor and the possible harm which might be done to the health of United States soldiers. The case is still pending in 1910.

The injury which might be done to navigation by the discharge of sewage was the subject of consideration by the New York Harbor Line Board in 1897 and 1908. On each of these occasions the Passaic Valley Sewerage Commission had asked permission to construct outfall works for their trunk sewer. On each occasion the Board confined itself strictly to a consideration of the effects upon navigation which might be produced in the channels of the harbor.

The section of the River and Harbor Act under which the Harbor Line Board and the Supervisor of the Harbor act here follows:

Section 13. That it shall not be lawful to throw, discharge, or deposit, or cause, suffer, or procure to be thrown, discharged, or deposited either from or out of any ship, barge, or other floating craft of any kind, or from the shore, wharf, manufacturing establishment, or mill of any kind, any refuse matter of any kind or description whatever other than that flowing from streets and sewers and passing therefrom in a liquid state, into any navigable water of the United States, or into any tributary of any navigable water from which the same shall float or be washed into such navigable water; and it shall not be lawful to deposit, or cause, suffer, or procure to be deposited material of any kind in any place on the bank of any navigable water, or on the bank of any tributary of any navigable water, where the same shall be liable to be washed into such navigable water, either by ordinary or high tides, or by storms or floods, or otherwise, whereby navigation shall or may be impeded or obstructed; Provided, That nothing herein contained shall extend to, apply to, or prohibit the operations in connection with the improvement of navigable waters or construction of public works, considered necessary and proper by the United States officers supervising such improvement or public work; And, provided further, That the Secretary of War, whenever in the judgment of the Chief of Engineers anchorage and navigation will not be injured thereby, may permit the deposit of any material above mentioned in navigable waters, within limits to be defined and under conditions to be prescribed by him, provided application is made to him prior to depositing such material; and whenever any permit is so granted the conditions thereof shall be strictly complied with, and any violation thereof shall be unlawful.

It will be noted that the provisions of this act state that it is unlawful to deposit refuse of any kind other than that flowing from streets and sewers and passing therefrom in liquid state into New York harbor or any tributary of it. The interesting question arises: Are the solids carried by sewage in suspension to be regarded as refuse in a liquid state? If it is not in liquid state the Supervisor may have jurisdiction over the disposal of sewage. This point has never been decided nor raised. The Supervisor confines himself to preventing ashes, garbage, sand and other coarse solid matters from being dumped by vessels into the harbor to the injury of navigation.

JURISDICTION UNDER INTERSTATE LAW

An agreement was entered into between the States of New York and New Jersey in 1833 to establish proper jurisdiction over the harbor for sanitary purposes. This

agreement was subsequently ratified by the Legislatures of both States and approved by Congress. It is in force at the present day.

Terms of the Agreement Between New York and New Jersey. Article 3 of this agreement states :

“The State of New York shall have and enjoy exclusive jurisdiction on and over all the waters of the bay of New York and over all the waters of such rivers lying west of Manhattan and to the south of the mouth of Spuyten Duyvil creek and over the land covered by the said waters below low water mark on the westerly or New Jersey side thereof, subject to the following rights of property and jurisdiction of the State of New Jersey.”

A perusal of this agreement and of various court decisions based upon it shows that the jurisdiction thus given to the State of New York covers all the waters of the Hudson river and New York bay and all vessels and craft of every kind while the same are afloat upon the waters. It was meant to be a jurisdiction for police and quarantine purposes. It was intended that vessels should not escape or evade the quarantine and other laws relating to passengers in New York by coming to anchor on the New Jersey shore or becoming attached to wharves or docks on the New Jersey side.

The jurisdiction of the State of New York, established by this agreement has, except as it relates to quarantine, been transferred to The City of New York for administrative purposes. The State of New York still manages and pays for the quarantine regulations of the harbor.

Application of this Agreement to the Disposal of Sewage from New Jersey. In order to determine whether the agreement of 1833 gives the State of New York power to impose restrictions upon the emptying of sewage into New York harbor from New Jersey the New York Bay Pollution Commission in 1905 obtained from State Attorney General John Cuneen an opinion on the following question :

What power, if any, has the State of New York to impose conditions upon the State of New Jersey as to constructing the Passaic valley sewer and operating it in the future?

The opinion of the Attorney General was that, while the two States of New York and New Jersey could enter into any negotiations they saw fit; yet New York could not impose any conditions in reference to the construction and operation of a sewer from New Jersey, which would be enforceable in any other way than by a proceeding in the United States Supreme Court to restrain the use and operation of such sewer. Thus, while the State of New York might pass a law prescribing a penalty for dumping sewage into the waters of the harbor, the penalty could not be enforced or collected in a

court of the State of New York against the State of New Jersey or any part of it. In the Attorney General's opinion the proper form in which to seek redress would be the United States Supreme Court.

It was upon this opinion that the State of New York brought suit against the State of New Jersey and the Passaic Valley Sewerage Commissioners to restrain the latter from constructing the Passaic valley sewer.

It is to be noted that the question put to the Attorney General implied a desire on the part of New York to use its supervisory power, not in a general way, but in a discriminating manner, against New Jersey. Whether the State of New York would have more power to enforce regulations against the discharge of sewage, if these regulations were made more general in application, is a question which has not been passed upon.

JURISDICTION BY NEW JERSEY

The restrictions which New Jersey is empowered to exercise over the discharge of sewage into New York bay are contained chiefly in the laws of that State passed in 1900, 1904 and 1907. It was intended that these laws should be administered by the New Jersey State Sewerage Commission, which was established by an Act of the Legislature approved March 24, 1899. The State Sewerage Commission, was, however, soon deprived of jurisdiction over conditions in the Passaic valley.

Jurisdiction of State Board of Health and Passaic Valley Sewerage Commission. By a recent Act of Legislature the State Sewerage Commission was combined with the State Board of Health and the laws relating to sewage disposal in New Jersey outside of the Passaic valley district are now, in 1910, enforced by the State Board of Health.

Chapter 72 of the Laws of 1900 specifically took from the protection of the State Sewerage Commission the waters of the ocean and the waters separating New Jersey from New York, for Section 42 of that Law states: "Waters of this state, as used in this act, shall not be held or construed to include the ocean or any waters separating this state from any other, unless such waters are used for potable purposes." The jurisdiction thus destroyed was restored by Chapter 313 of the Laws of 1904.

The Act now existing, Chapter 135, Laws of 1907, is short and shows the relation of the Board of Health of New Jersey to New York harbor and to the project of the Passaic Valley Sewerage Commissioners. It will be noted that the last section of the law specifically states that this Act does not repeal or in any way affect or modify the provisions of any Act conferring power and authority upon the Passaic Valley Sewerage Commissioners. The conditions of sewage disposal in the Passaic valley, relating

as they do to a population which amounts to 28 per cent. of the entire population of the State, are wholly within the jurisdiction of the Passaic Valley Sewerage Commission and cannot be regulated by any other body, except the Legislature itself.

So far as ascertained, the New Jersey Law has never been invoked to protect the harbor of New York against pollution, although it has been used to stop local nuisances due to sewage along the Hoboken docks, and is in force to prevent excessive pollution of the waters of the New Jersey metropolitan district outside of the jurisdiction of the Passaic Valley Commission.

The Passaic Valley Commission is charged with the duty of protecting the Passaic river against sewage pollution and has no responsibility with respect to the pollution of New York harbor. The original Act which created a Passaic valley commission was enacted February 26, 1896. The original Act under which the Passaic valley sewerage district was created was approved March 27, 1902. This Act was amended April 22, 1903.

Principal Laws of New Jersey with Respect to Sewage Disposal. Following is the text of the principal law of the State of New Jersey with respect to the disposal of sewage, outside of the Passaic valley, except the Law of 1899 which provides for the formation of sewerage districts and under which the Passaic Valley Commission was organized. It is Chapter 135 of the Laws of 1907:

1. The State Sewerage Commission is hereby authorized and empowered to inspect any of the waters of this State, and if it finds any of the waters of this State are being polluted in such manner as to cause or threaten injury to any of the inhabitants of this State, either in health, comfort or property, it shall be its duty to notify, in writing, any person, municipal or private corporation found to be polluting said waters that prior to a time to be fixed by said commission, which time shall not be more than five years from the date of said notice, said person or corporation must cease to pollute said waters and make such other disposition of the sewage or other polluting matter as shall be approved by said commission; any person or corporation aggrieved by any such finding may appeal therefrom to the Court of Chancery at any time within three months after being notified thereof; and the said Court is hereby authorized and empowered to hear and determine such appeal in a summary manner, according to its course and practice in other cases, and thereupon to affirm, reverse or modify the finding of said commission in such manner as it may deem just and reasonable.

2. The State Sewerage Commission is hereby authorized to apply to the Court of Chancery for writ of injunction to prevent any violation of or enforce the provisions of this act and the act to which this is a supplement, and it shall be the duty of the said court, in a summary way, to hear and determine the merits of said application; and in all such cases to restrain violation of or enforce the provisions of the said acts.

3. "Waters of this State," as used in this act and the act to which this is a supplement, shall include the ocean and its estuaries, all springs, streams and bodies of surface or ground water, whether natural or artificial, within the boundaries of this State or subject to its jurisdiction.

4. All acts or parts of acts inconsistent with this act are hereby repealed, and this act shall take effect immediately; provided, that this act shall not repeal or in any way affect or modify the provisions of any act conferring power and authority upon the Passaic Valley Sewerage Commission in relation to the purification of the Passaic river and the streams tributary thereto, and particularly shall not be deemed taken or held to modify or affect the provisions of an act relating to the purification of the waters of the Passaic river, within the Passaic valley sewerage district, approved March eighteenth, one thousand nine hundred and seven.

Practical Results of New Jersey's Jurisdiction. In the administration of its laws the New Jersey Sewerage Commission and the New Jersey State Board of Health have made inspections, given advice, served formal notices to abate pollution, supervised upwards of 70 disposal plants and ordered a number of suits for injunctions to enforce its orders with respect to sewage disposal. Since the jurisdiction of the commission over the ocean shores of the State was restored, progress has been made in bringing about a sanitary disposal of the sewage wastes which formerly in large quantity fouled the beaches and bathing places of the crowded summer resorts of Monmouth County. The commission has also done much to call attention to the unsanitary and dangerous conditions of sewage pollution connected with the extensive shellfish industries of New Jersey. Nothing has been done to suppress the evils of pollution of New York harbor, except in strictly local circumstances. The project of the Passaic Valley Sewerage Commission, for the benefit of whose plans much of the Legislation regulating the State's jurisdiction over sewage disposal has been passed, does not require comment here.

JURISDICTION BY THE STATE OF NEW YORK

Jurisdiction by the State of New York over the disposal of sewage is exercised under the Public Health Law by the State Commissioner of Health.

General Powers and Duties of the Health Commissioner. The general duties and powers of the Commissioner require that he shall take cognizance of the interests of health and life of the people of the State in all matters pertaining thereto. The Law states that he shall obtain, collate and preserve such information referring to mortality, disease and health as may be useful in the discharge of his duties, or may contribute to the promotion of health or the security of life in the state. He may reverse or modify any order, regulation, by-law or ordinance of a local board of health concern-

ing a matter which, in his judgment, affects the public health beyond the territory over which such local board has jurisdiction. The Commissioner has all necessary powers to make examinations into nuisances or questions affecting the security of life and health in any locality.

The Governor of the State may require the Commissioner of Health to make examinations and report, and these reports, when approved by the Governor, enable the latter to declare matters public nuisances which may be found and certified in such reports to be nuisances and the Governor may order them to be changed, abated or removed, as he may think proper. It is customary for the Governor to follow this course of action when circumstances require.

Specific Powers of the Health Commissioner with Respect to Sewage Disposal. Article 5, Section 75, of the Public Health Law, states that no person, corporation or municipality shall place or cause to be placed or discharged into any waters of the State, unless permitted by the State Commissioner of Health, any decomposable or putrescible matter of any kind or any substance injurious to the public health. Exception is made of such wastes as come from drains or sewers already in operation or from extensions or modifications of the same, provided the refuse or waste matter discharged therefrom is not materially changed or increased. It is to be noted that this exception does not permit any material increase in the discharge of sewage, nor does it permit the discharge of sewage from a sewer system which has been extended, modified or constructed subsequent to the passage of this act.

Compulsory Reports from Municipalities. Provision for reports as to conditions of sewerage and sewage disposal is made in Section 79 of Article 5 of the Public Health Law. This section states that it is the duty of the public authorities having by law charge of the sewer system of any municipality in the State from which sewage is discharged into the waters of the State to file with the board of health of the municipality in which an outlet is located a report of each sewerage system having an outlet within the municipality concerned. This report must comprise such facts and information as the State Commissioner of Health may require and is to be placed on blanks or forms to be furnished by him on application. The local board of health being satisfied as to the correctness and completeness of the report, the board shall within 30 days after its receipt certify the same and transmit it to the State Commissioner of Health. Such report, when satisfactory to the State Commissioner of Health, shall be filed by him in his office and shall constitute evidence of exemption from the prohibition of the Public Health Law. No sewerage system is exempt from prohibition for which a satisfactory report has not been filed in the office of the State Commissioner of Health in accordance with this section.

Penalties. Section 79d, Article 5, of the Public Health Law, specifies the penalty which may be imposed for failure to comply with the requirements of the Health Commissioner. The penalty for the discharge of sewage from any public sewer system into any of the waters of the State without filing a report is \$50. The penalty for the discharge of sewage from any new or extended public sewer system into any of the waters of the State without a duly issued permit is \$500, and the further penalty of \$50 per day for each day the offense is maintained. The penalty for discharging refuse or waste matter from any industrial establishment without a permit is \$100 and \$10 per day for each day the offense is continued. The penalty for discharging into any waters of the State any other matter prohibited by the Public Health Law beside that specified above is \$25 and \$5 a day for each day the offense is maintained.

Regulations other than the Health Law Applicable to Prevent Pollution by Sewage. In addition to the foregoing health laws, the State of New York prohibits the pollution of water through the forest, fish and game laws and through the penal code.

Section 52 of the Forest, Fish and Game Laws of New York State prohibits the discharge of dyestuffs, coal tar, refuse or other deleterious or poisonous substances from being thrown or being allowed to run into waters of the State in quantities destructive of fish inhabiting the same.

Section 390 of the Penal Code prohibits the throwing or discharging of gas tar or the refuse of a gas house or gas factory, or offal, refuse or other noxious or poisonous substances into any public waters or into any sewer or stream entering or running into such public waters and specifies that any person who permits these offenses is guilty of a misdemeanor.

Practical Results. Within recent years the State Department of Health has added materially to its former usefulness in the matter of regulating the conditions of sewage disposal. It maintains a bureau of sanitary engineering to assist it in exercising proper jurisdiction over the pollution of waters and the disposal of sewage. This bureau examines plans for sewerage and sewage disposal, makes investigations relative to sewerage and sewage disposal problems, and prepares plans for sewerage and sewage disposal for the State institutions. Investigations are also made of complaints relating to stream pollution and of various other technical subjects. The net result of this work has been beneficial to the State and has led to a better general understanding of the question of pollution of water by sewage and its danger to the public health and welfare.

The State Department of Health exercises jurisdiction over sewerage and sewage disposal in the metropolitan sewerage district up to, but not including, the limits of

the City of New York. It has, however, made inspections of the sewage disposal plants in the City of New York and printed descriptions of them in the 1907 annual report of the Commissioner of Health.

The Department has taken no positive attitude with respect to the discharge of sewage into the harbor of New York although it was expected to take a definite position with regard to it in connection with the Bronx valley sewerage project. A report was made by the sanitary engineering bureau of the State Department of Health, which was favorable to the enterprise. The Commissioner was preparing to give the plans his official sanction or disapproval when he was relieved of the duty of taking action upon them by the Attorney General of the State, who, upon request, furnished the State Commissioner of Health and the State Engineer and Surveyor with an opinion to the effect that the Bronx valley project had been taken by special legislation out of their respective jurisdictions.

The Bronx Valley Commission, like the Passaic Valley Commission, exists for the specific purpose of sanitating a river valley by the construction of a trunk sewer which is to discharge into New York harbor. The Bronx Valley Commission is not charged with the duty of protecting the purity of the harbor waters.

JURISDICTION BY THE CITY OF NEW YORK

Local authority over systems of sewerage and sewage disposal within the limits of The City of New York is divided between the Borough Presidents, the Board of Estimate and Apportionment, the Board of Health and the Board of Aldermen.

Duties of Borough Presidents. When the Charter of the City was adopted all powers and duties which had been conferred upon any of the officers of The City of New York, or any of the other municipalities consolidated, which in any way related to public sewers were vested in The City of New York and as a matter of administration devolved upon the Presidents of the Boroughs.

It is the duty of the Borough President of each borough to devise and prepare, subject to the approval of the Board of Estimate and Apportionment, a plan for the proper sewerage and drainage of the borough over which he presides, so far as the same has not already been done. This is clearly stated in Section 444 of the Greater New York Charter.

The President of each borough must, subject to the same approval, lay out in his borough as many sewerage districts as may be necessary and he must determine and show on suitable maps the location, course, size and grade of each sewer and drain proposed for each district and prepare a complete plan of the proposed sewerage for the whole territory over which he has jurisdiction.

Upon the completion of the map for the drainage of any district and its approval by the Board of Estimate and Apportionment, such plan is to be regarded as the permanent plan for the sewerage district. It is subject, however, to such subsequent modifications as may, in the opinion of the Borough President and the Board of Estimate and Apportionment, become necessary in consequence of alterations made in the location or grade of any street, or for other reasons.

Copies of the formally approved map or plan and of any maps showing necessary modifications must be certified by the Mayor and the Secretary of the Board of Estimate and Apportionment, whereupon they are to be filed, one copy in the office of the Corporation Counsel, one in the office of the President of the Borough, and one in the office in which conveyances of real estate are required to be recorded.

This description of the method of planning and constructing sewers shows clearly that the Board of Estimate and Apportionment was intended to be a controlling central body, which would exercise jurisdiction over the construction of all sewers in the different boroughs of the city. It also shows that the need of a plan of sewers made long in advance of actual requirements was recognized, and that this plan, once made, should be altered as little as practicable. There is no indication that a comprehensive general plan was thought necessary.

In order to assist him in devising proper sewerage facilities the President of each borough may at any time employ, when authorized by the Board of Estimate and Apportionment and the Board of Aldermen, a consulting engineer, who shall be an expert in all matters regarding sewers and highways. This engineer must have had 15 years experience.

Discharge of Sewage. There is no statement in the Charter as to where the sewage of New York may be discharged in order to avoid nuisance or injury to the public health. On the contrary it is stated in Section 392 that any overflow sewers which may be deemed necessary for the relief of any sewers now constructed or which may hereafter be constructed in the city shall be discharged into the waters adjacent to the city or into the Gowanus canal or into any other canal or inlet at such points as, in the judgment of the President of the Borough, may be most convenient. It was in accordance with this section, that so-called overflow sewers were constructed so as to discharge into Gowanus canal, with the result of polluting the waters of that canal beyond permissible limits.

Temporary and Private Sewers. Provision is made in Sections 394 and 395 of the City Charter for the construction of temporary sewers by the City and private sewers by individuals.

A borough president may construct a sewer or drain for the purpose of preventing damage to property or to avoid a nuisance or when it becomes impracticable to proceed immediately to the construction of a sewer in accordance with a plan previously adopted. Construction of temporary sewers, also, requires the approval of the Board of Estimate and Apportionment.

Private sewers can be constructed without the consent of the Board of Estimate and Apportionment, provided they conform to the general plan of sewerage for the district in which they are to be located and certain other formalities are complied with. These private sewers become the property of The City of New York and are deemed to be fully dedicated to the City when their total cost is fully paid by the owners of the abutting property.

Sewage Disposal Works. Power to construct and maintain sewage disposal plants and their necessary appurtenances is granted with the authority to construct sewers, and this work is done in compliance with the same laws and regulations which apply to the construction and maintenance of sewers, it being the intent and meaning of Section 401 of the Charter that sewage disposal works shall be construed as part and parcel of a sewer.

Inasmuch as the sewage of New York is, for the most part, discharged into the harbor and its tributaries without regard for consequences, the number of sewage disposal works which have been built is small. A half-dozen plants have been constructed to purify sewage before discharging it upon low-lying meadow lands through which it would otherwise flow for a considerable distance before reaching the ocean and these plants have been built and maintained by the Borough Presidents without permission, advice or regard for the opinions or regulations of any health authority.

Local Board of Health Control. It is specified in Section 1168 of the City Charter that the duties and powers of the Board of Health shall extend over The City of New York and the waters adjacent thereto within the jurisdiction of the City and over the waters of the bay within the quarantine limits established by law, but shall not be held to interfere with the powers and duties of the Commissioners of Quarantine or the Health Officer of the Port.

The Commissioners of Quarantine, now abolished, and the Health Officer of the Port, their executive officer who now remains in office, have never had anything to do with sewerage or sewage. Their concern has exclusively been in managing the quarantine of the Port of New York for the State.

The head of the Department of Health is called the Board of Health. This Board consists of one Commissioner, the Police Commissioner of the City and the Health

Officer of the Port. The Commissioner of Health is the executive officer of the Health Department.

Section 1169 of the Charter states that it is the duty of the Board of Health to aid the enforcement and, so far as practicable, to enforce the laws of the State applicable in The City of New York to the care, promotion and protection of human life.

The Law under which the Board acts is intended to include all necessary laws relative to cleanliness and sanitary supervision. The City Charter specifies that care shall be exercised by the Board of Health over the public water supply, but says nothing about the discharge of sewage into the harbor.

The Sanitary Code. The Board of Health is authorized by the Charter to pass on and publish such regulations for the security of life and health in The City of New York as may be required and to this end to make certain regulations. The regulations of the Board constitute what is known as the Sanitary Code. They may be enforced by such fines, penalties and imprisonment as are prescribed for the enforcement of the ordinances of the City.

The Board of Health may include in the Sanitary Code all matters and subjects over which the power and authority of the Department extend, not limiting their application to the subject of health only.

The Board is not required to confine itself to the abilities of its staff of regular employees. It is permitted from time to time by Section 1186 of the Charter to employ a suitable person or persons to render sanitary engineering service and to make or supervise practical scientific investigations and examinations in the city requiring engineering skill and to prepare plans and reports relative thereto. The Department has a sanitary engineer regularly employed on its staff.

Practical Work of the City Department of Health. The Sanitary Code contains several regulations with respect to the disposal of sewage. It is stated in Section 38 that no person or persons or corporation shall permit sewage or drainage, factory refuse or foul or offensive liquid or other material to discharge into the waters of any river, stream, canal, harbor, bay or estuary or into the sea within the city limits, except under low water mark and in such manner and under such conditions that no nuisance can be caused thereby.

The discharge of gas tar and other offensive wastes from gas houses into the public waters or sewers connected therewith is prohibited by Section 89 of the Sanitary Code.

Prompt removal of sewage from the sewers is provided for in Section 28. It is the duty of the boards, departments and officers having the power to do so to cause

sufficient water to be used and other adequate means taken so that whatever substances may enter any sewer "shall pass speedily along and from the same and sufficiently far into some water or proper reservoir, so that no accumulation shall take place and no exhalation proceed therefrom dangerous or prejudicial to life or health."

The Code provides in Section 26, that no bathing establishment shall be maintained in The City of New York or along the waterfront of the city without a permit from the Board of Health.

By a recent provision of the Code, Section 185, it is unlawful to hold, keep and offer oysters for sale without a permit in writing from the Board of Health and subject to the rules and regulations of said Board.

Other sections of the Sanitary Code relate to the proper management of plumbing, cesspools and privies. The Department exercises its jurisdiction to prevent the pollution of drinking water, but not to prevent insanitary conditions at the sewer outfalls. In the year 1907 over 1,000 inspections, resulting in about 500 orders, were made by the Department of Health to abate the pollution of the water supplies of Staten Island. Eventually the Department ordered that the water company supplying the water discontinue the use of the surface water complained of until the company could provide itself with filter beds.

The Department of Health causes systematic inspections to be made of the shores of the Boroughs of Brooklyn and Richmond and collects and disposes of much offal which has been carried to the shores by the harbor waters. In the year 1907 the number of inspections was 4,941; the number of bodies of men and animals found and disposed of was 4,421, and the number of parts of animals and of clothing and bedding was much greater.

A perusal of the foregoing statements concerning the powers and duties and work of the Department of Health shows that authority is not lacking, that good is accomplished by it, but that the Board of Health exercises no jurisdiction over the discharge of sewage into the waters of New York harbor. The Board does not prevent accumulations of solid matters in the sewers nor the escape of exhalations from them.

Board of Aldermen. In addition to the powers of the Board of Health the Board of Aldermen have power to make regulations concerning the public bathing establishments which are situated along the waterfront, often close to sewer outfalls. Paragraph 12 of Section 9 of the Charter gives the Board of Aldermen power to regulate swimming and bathing in the waters of the city, to establish and maintain such public baths and public comfort stations as may be necessary and to establish suitable rules

LEGAL JURISDICTION PROPOSED BY THE NEW YORK CHARTER COMMISSION OF 1909

By changes proposed by the Charter Commission relative to sewerage and sewage disposal in The City of New York the duty of making plans for improvements in The City of New York are placed within the province of a bureau of public improvements and engineering under the Board of Estimate and Apportionment, while the executive work of building sewers and sewage disposal works will fall to a bureau of sewers under the department of street control.

Careful study of the plan of reorganization fails to reveal specific mention of a comprehensive plan of sewage disposal and the question of sewerage itself receives scant attention.

The Bureau of Public Improvements and Engineering of the Board of Estimate and Apportionment. The Borough Presidents would be relieved of administrative duties such as they now perform and would give their undivided time and attention to the work of the Board of Estimate and Apportionment, which would then become the great financial executive committee of the City. For the more perfect co-ordination of the City business, greater protection of its rights, better preservation of its property, the establishment of large economies in its purchases, and a comprehensive and systematic plan for its growth, a number of new bureaus would be created in the Board of Estimate and Apportionment. One of the many subdivisions would be a bureau of Public Improvements and Engineering. The head of this bureau would be an engineer resident in the city and of at least 10 years' professional experience. He would be known as City Engineer.

Among its manifold duties the new Board of Estimate and Apportionment would have charge of the mapping and planning of the city and would lay out new streets, parks, bridges and tunnels, widen, straighten, extend, alter and close existing streets, and fix, establish and change the grades of streets. It would select the sources for the supply of drinking water and buy property needed for the same.

The powers and duties of the Department of Health would remain practically the same as they now exist. It is specified that there shall be in the Department, in addition to such other bureaus and offices as may be established therein by the Board of Estimate and Apportionment, a bureau of sanitation, the chief officer of which shall be called the sanitary superintendent, who, at the time of his appointment, shall have been for at least 10 years a practising physician and for three years a resident of the city.

No reference to sewerage or the disposal of sewage is made in that part of the proposed Charter which relates to the duties and powers of the Department of Health.

The Bureau of Sewers of the Department of Street Control. The department of street control would be presided over by a commissioner who would have charge of the sweeping and cleaning of streets, removing or otherwise disposing of ashes, street sweepings, garbage, dead animals, offal, light refuse and rubbish, the removal of snow and ice, regulating, curbing, flagging and guttering streets and laying crosswalks, filling sunken lots, issuing permits to use and open streets, constructing, maintaining, repairing and cleaning sewers and drains, the location, establishment, care, erection and maintenance of baths, public urinals and public comfort stations and preparing a map of all existing underground pipes, mains, sewers and other subsurface structures, and performing a large number of other duties. Under the commissioner of street control would be a number of bureaus, and among them a bureau of sewers, the head of which would be known as the chief of the sewer bureau.

The commissioner could, when authorized by the Board of Estimate and Apportionment, employ a consulting engineer, who should be expert in all matters relating to sewers and highways. This engineer should have had 10 years' professional experience. The power of constructing sewers and drains would include the power to construct, operate and maintain sewage disposal works and their necessary appurtenances. The cost of conducting sewage disposal works would, in the discretion of the Board of Estimate and Apportionment, be in whole or in part an assessment upon the property benefited.

CHAPTER XIII

SALINITY OF THE WATERS

The investigations described in this chapter were made in order to determine the proportions of land water and sea water in New York harbor throughout the year. The results show the conditions observed at 11 different points, mostly at light-vessels and lighthouses, including Ambrose Light at the sea entrance to the harbor, Passaic Light in Newark bay, Governors Island in Upper New York bay, Throgs Neck at the Sound entrance of the East river, and Tarrytown in the Hudson river.

The data corroborate in an interesting manner many of the facts brought out in the tidal studies described in Part III, Chapter III of this report. Among further details the information is of service in showing how large is the normal amount of sea water in the harbor and how variable is the flushing action which the rivers produce upon the harbor at different seasons of year.

In addition to the routine examinations which were made at the light-vessels and lighthouses numerous observations were made from time to time for special purposes at other points. The method of examination was in all cases the same.

SECTION I

ROUTINE OBSERVATIONS

The tests of salinity were made by noting the specific gravity of the water by means of simple, yet accurate, apparatus. When suitably interpreted, these gave the salinity of the water. By assuming that the salinity was due to sodium chloride, an assumption which was a sufficiently close approximation to the truth, the amount of chlorine, which is a familiar term in water analysis, could be determined.

Method Adopted. Specific gravity determinations were employed because they could be rapidly and easily made by men who were neither trained chemists nor expert in the handling of delicate apparatus and who were, nevertheless, capable of making regular observations with a simple outfit. The Hilgard Ocean Salinometer, which is a standard instrument for such work, was found to be too fragile for the use proposed, and it, moreover, required that the water to be tested should be brought to a standard temperature. A salinometer was, therefore, designed especially for this work. It consisted of a specific gravity float or hydrometer with a thermometer in its centre.

By this arrangement the thermometer and hydrometer could be read almost simultaneously with small chance of error. The height of the hydrometer was about 30.5 cm. The range of the hydrometer scale was from 1.000 to 1.030, and the range of the thermometer scale was from 20 degrees to 110 degrees Fahrenheit. The readings of the thermometer and hydrometer were recorded by the observers in notebooks prepared for the purpose, and these records were subsequently transcribed and reduced to an equivalent of the specific gravity readings at 60 degrees Fahrenheit.

Standards. Before the tests were begun it became necessary to establish standards for what is here termed land water and sea water, in order that a clear and definite idea might be conveyed when using either expression and in order to calculate the relative salinity present. Land water is the term used by the Commission to designate the water of inland rivers and streams and is distinguished from sea water, which is the water of the ocean beyond appreciable influence of water from the land. The term fresh water has not been used in connection with this work, since the quality of freshness may be possessed by any water irrespective of its saline character.

The salinity of sea water varies in different parts of the ocean according to the quantity of salts present in solution, but in the vicinity of New York it may be taken to contain 18,000 parts of chlorine per million parts of water. The specific gravity of water of this salinity is 1.025. The salinometers were graduated to differences of 0.0005, corresponding to 360 parts of chlorine. Errors of reading were probably not over one per cent.

Analytical determinations of the amount of chlorine present in samples of water were made for comparison with the amounts calculated to be present by the use of the salinometer, with the results shown in Table I.

TABLE I

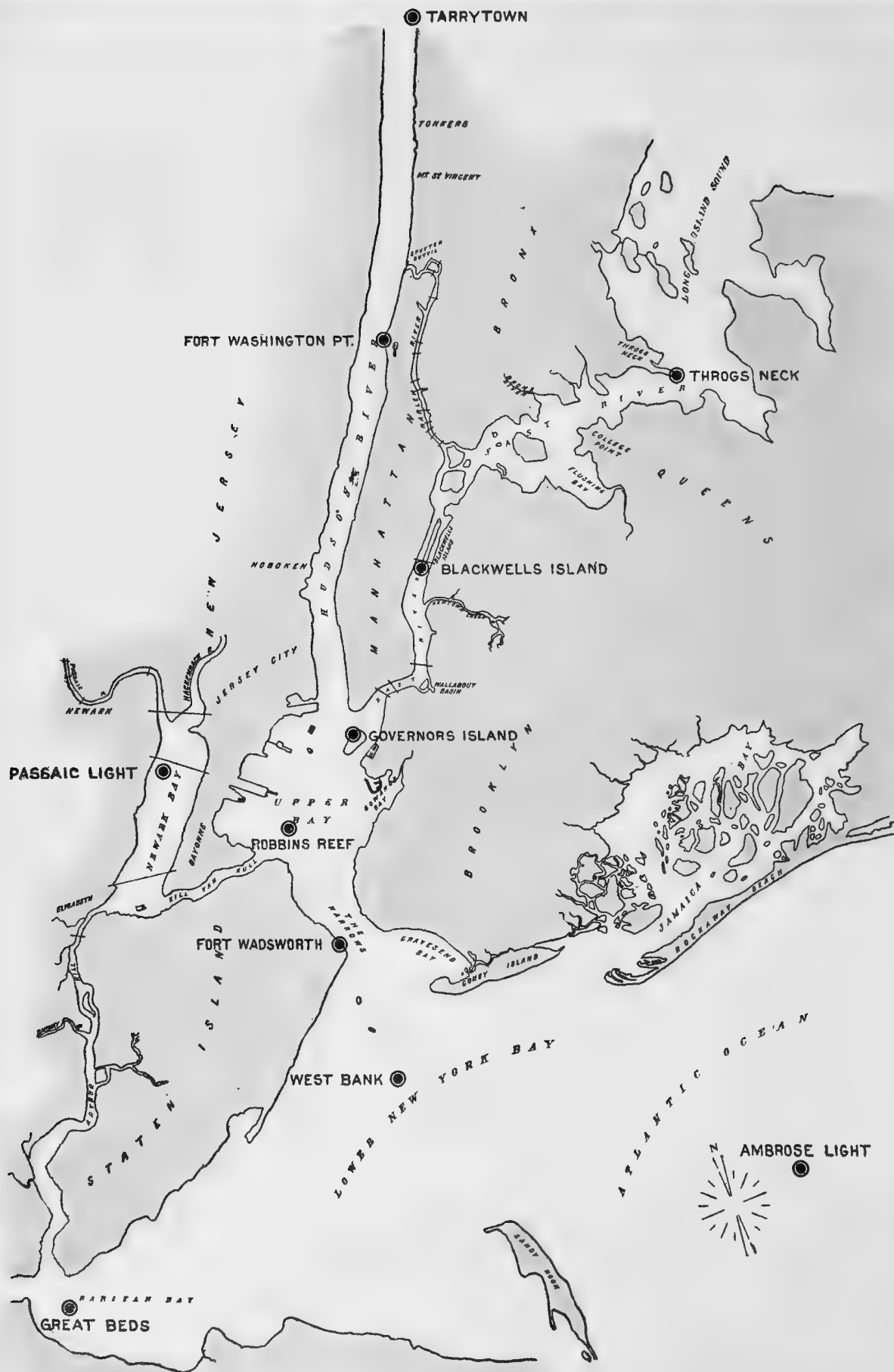
COMPARISON BETWEEN CHLORINE IN WATER AS ESTIMATED BY SALINOMETERS AND BY ANALYSIS

Salinometer readings	Number of tests	Estimated Chlorine	Actual Chlorine Average of tests
1.007	6	5,040	4,946
1.0105	1	7,560	7,432
1.011	2	7,920	7,888
1.0113	1	8,136	7,923
1.012	5	8,640	8,659
1.0125	1	9,000	8,772
1.0128	1	9,216	9,125
1.013	1	9,360	9,550
1.0135	1	9,720	9,125
1.014	1	10,080	9,479

From these results the method adopted is believed to be sufficiently accurate to secure results correct within about two per cent. after allowing for errors of observation.

In determining the correction to be applied to reduce the ratings of the salinometer and thermometer to the reading which would occur at the standard temperature of 60 degrees Fahrenheit the instruments were immersed and read in solutions of varying salinity raised to 80 degrees Fahrenheit and lowered to 32 degrees Fahrenheit, readings being taken at each degree. The average of a number of these observations taken for each temperature was then plotted and a diagram showing the temperature correction to be applied to the readings as made by the observers at the several stations was prepared.

Location of the Salinometer Stations. In order to obtain the percentage of land water in the main divisions of the harbor and at various stages of tide, observations were made with the co-operation of the United States Lighthouse Board at 11 stations during the year 1909, as shown in Table II.



Location of Salinometer Stations



Testing the Salinity of the Water at Ambrose Light Vessel. In this way the relative amount of land and sea water at eleven points in the harbor was determined three times each day for a full year



Salinometer Station. This was one of the eleven stations where tests were made every day for a year to show the amount of salt in the water

TABLE II

LOCATION OF SALINOMETER STATIONS

Ambrose Lightship	Atlantic ocean
West Bank Light	Lower bay
Great Beds Light	Raritan bay
Fort Wadsworth	The Narrows
Robbins Reef	Upper bay
Passaic Light	Newark bay
Governors Island	Upper bay
Fort Washington Point	Hudson river
Tarrytown Light	Hudson river
Blackwells Island	East river
Throgs Neck	Entrance to Long Island Sound

The observations were made at 8 a. m., at noon and at 4 p. m. daily. The observations included in each period of five days thus covered practically every hour of the tide. The results were therefore averaged for five-day periods. The observations were confined, for the most part, to surface water.

Data Collected. The average results for each month of the year 1909 are given in Table III.

TABLE III

SUMMARY OF ROUTINE SALINOMETER OBSERVATIONS

Percentage of Land Water at the Surface

1909		Ambrose Lightship	West Bank	Fort Wadsworth	Robbins Reef	Governors Island	Blackwells Island	Great Beds	Passaic Light	Fort Wash- ington Point	Tarrytown	Throgs Neck□
January.....	All*	1.3	19.3	29.0	24.9	30.9	26.5	31.7	65.8	62.2	84.6	15.9
	Out†	....	19.7	28.2	23.3	29.4	26.5	33.1	63.8	60.7	84.8	15.8
	In‡	....	18.3	30.0	24.6	33.7	26.1	29.2	67.3	63.2	84.5	16.0
February.....	All	6.5	34.2	50.7	42.6	40.5	35.9	47.1	82.2	83.3	97.2	19.3
	Out	....	35.8	50.8	41.8	39.0	36.9	49.5	81.0	83.2	97.4	19.8
	In	....	33.4	52.4	42.8	43.4	34.6	44.1	84.0	83.7	97.0	18.7
March.....	All	10.2	35.0	50.5	43.2	49.3	37.8	46.5	83.4	84.0	98.6	20.8
	Out	....	34.5	49.9	43.3	49.1	38.0	48.6	83.5	83.9	98.6	21.2
	In	....	34.9	51.0	44.4	49.9	37.6	44.5	83.3	84.0	98.7	20.7

* "All" means average of all records made during ebb and flood currents and during slack water.

† "Out" means average of all records made during ebb currents.

‡ "In" means average of all records made during flood currents.

□ Throgs Neck: "In" means westerly currents.

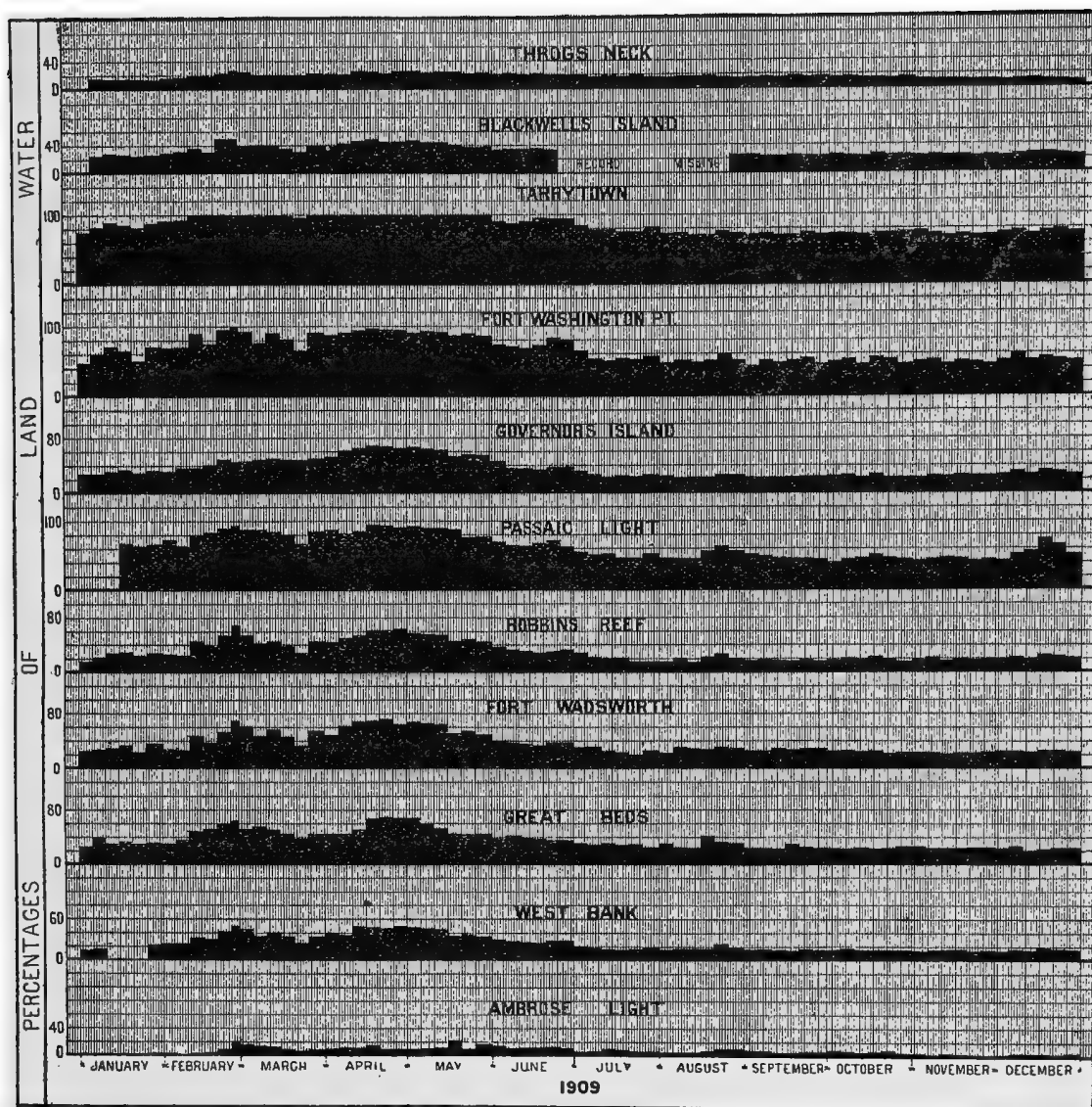
DATA COLLECTED

TABLE III—*Continued*

1909		Ambrose Lightship	West Bank	Fort Wadsworth	Robbins Reef	Governors Island	Blackwells Island	Great Beds	Passaic Light	Fort Wash- ington Point	Tarrytown	Throgs Neck□
April.....	All	10.8	45.1	64.9	56.1	64.0	45.4	58.2	90.6	94.7	100.0	23.8
	Out	....	44.3	59.8	55.6	60.1	45.3	59.4	90.3	94.7	100.0	23.5
	In	....	45.6	67.9	55.8	67.2	44.9	57.0	90.9	95.1	100.0	24.2
May.....	All	15.6	42.2	59.1	52.4	59.1	42.3	53.6	86.3	90.6	99.9	24.3
	Out	....	41.7	56.0	52.5	56.6	41.7	55.5	85.7	90.7	99.8	24.0
	In	....	41.6	61.0	51.6	61.0	42.9	50.7	86.8	90.5	99.9	24.5
June.....	All	13.0	27.8	38.4	34.0	39.5	33.7	37.6	67.2	74.5	93.1	21.3
	Out	....	28.5	38.0	33.6	38.7	34.0	38.9	66.3	74.4	93.4	21.4
	In	....	27.3	39.1	33.8	38.9	33.4	36.1	67.8	74.7	92.8	21.2
July.....	All	6.9	17.3	25.5	21.5	25.3	27.7	28.7	51.0	56.0	80.2	18.1
	Out	....	17.1	24.3	21.1	24.6	26.8	29.3	50.0	56.0	80.4	18.2
	In	....	17.5	28.2	21.6	27.5	28.2	28.0	51.8	55.7	80.0	18.0
August.....	All	7.2	18.4	29.5	21.4	24.9	25.5	29.6	52.6	51.8	74.4	17.3
	Out	....	17.5	28.7	21.6	23.8	26.5	31.4	52.2	52.4	75.2	17.7
	In	....	19.4	30.2	21.3	26.0	24.4	27.1	53.6	50.6	73.7	17.0
September.....	All	6.8	16.2	28.3	18.3	22.2	24.1	26.2	47.5	48.8	73.0	17.1
	Out	....	16.6	24.8	18.3	19.7	24.3	26.4	47.3	49.0	73.5	16.9
	In	....	16.0	32.3	18.6	24.9	23.8	25.9	48.3	48.3	72.6	17.4
October.....	All	6.0	15.7	22.2	19.6	24.7	25.6	23.9	46.4	50.4	73.8	15.5
	Out	....	15.4	21.5	19.3	22.8	25.2	24.5	46.2	49.5	74.4	15.0
	In	....	16.0	25.5	20.4	27.0	26.2	23.4	46.1	50.8	73.4	15.9
November.....	All	4.6	15.2	22.7	19.7	25.1	24.2	24.9	45.3	49.4	73.4	13.2
	Out	....	14.7	22.2	19.7	24.1	24.5	25.0	44.6	49.7	73.5	13.3
	In	....	15.7	23.0	19.5	26.4	23.8	24.9	45.8	48.4	73.3	13.2
December.....	All	4.6	17.5	25.3	22.3	30.0	25.7	23.6	57.6	53.7	76.4	11.6
	Out	....	17.4	23.6	21.9	28.1	25.6	23.2	56.0	53.0	76.5	11.4
	In	....	17.9	27.3	22.8	32.5	25.8	23.9	59.0	54.4	76.3	11.7
Averages for year..	All	7.6	25.2	37.2	31.2	36.4	31.9	35.8	64.2	66.3	85.3	18.1
	Out	....	24.8	34.8	30.4	34.6	31.9	37.2	63.8	66.3	85.7	18.2
	In	....	24.1	37.5	30.4	37.0	31.9	34.5	64.9	65.1	84.9	18.1

□ Throgs Neck: "In" means westerly currents.

Comments on the Results. The influence of the land water discharged by the rivers during the spring freshets is clearly seen in the relatively large percentage of land water present at all points during April. The full effect of this outflow was not felt at



PROPORTIONS OF LAND WATER AND SEA WATER
IN NEW YORK HARBOR

TOTAL NUMBER OF OBSERVATIONS — 11,800

Ambrose Light-vessel until May, when there was an average of 15.6 per cent. of land water, or more than twice the average for the year. At Passaic Light there was 90.6 per cent. in April against 64.2 for the year; at Robbins Reef 56.1 per cent. against 31.2 for the year; and at Fort Washington Point 90.6 per cent. against 66.3 for the year.

At Throgs Neck the maximum per cent. of land water was 24.3 in May, as compared with 18.1 per cent. for the entire year. At Tarrytown the records indicate that the river contained no sea water in April. On the other hand, at Ambrose Light-vessel in January there was but 1.3 per cent. of land water. The least amount of land water at Robbins Reef occurred in September, when it amounted to 18.3 per cent. At Throgs Neck the least was in December, being then 11.6 per cent.

Taking the year as a whole, there was but little difference recorded in the salinity between outgoing and incoming currents, but for considerable periods a preponderance of land water was observed on the flood currents at certain stations, notably Fort Wadsworth, Governors Island and Fort Washington Point. Upon investigation this condition, which seems to be unreasonable, was found to be due, at least at Fort Washington Point, to an eddy which flowed in a direction opposite to that of the prevailing current in the main channel of the river, for a considerable part of the time. The explanation in the other cases was not apparent. The fact that samples were taken from the surface and near shore may have influenced the results.

Another curious fact noted was that there seemed to be more land water at the Narrows than in the Upper bay, although the latter was farther from the ocean. The figures average 37.2 per cent. for the land water at Fort Wadsworth and 31.2 per cent. for the land water at Robbins Reef. It seems probable that the larger amount of land water at Fort Wadsworth was due to the discharge of land water from the Passaic and Hackensack rivers at the head of Newark bay. This water, apparently, passed through the Kill van Kull and hugged the Staten Island shore on its way out through the Narrows, thus passing south of Robbins Reef.

SECTION II

MISCELLANEOUS OBSERVATIONS OF SALINITY

Lower Bay. Among the more important determinations of salinity which were made at different times and places below the Narrows are those recorded in Table IV. These observations were not sufficient in number to warrant conclusions of a sweeping nature, but they are of interest as showing the conditions which occur at the times and places stated.

SALINITY OF THE WATERS

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TABLE IV

RESULTS OF MISCELLANEOUS SALINITY OBSERVATIONS AT VARIOUS DEPTHS BELOW THE
SURFACE IN THE LOWER BAY

Location	Depth in feet	Date	Current	Per Cent. land water	Remarks
Ocean 10 miles off Long Branch.....	Surface	1909 July 21	Flood	4	Temperature 67°
Ocean 10 miles off Long Branch.....	145	" "	Flood	0	Temperature 57°
Ocean 12 miles off Long Branch.....	Surface	" "	Flood	4	Temperature 66°
Ocean 12 miles off Long Branch.....	150	" "	Flood	0	Temperature 57°
Ocean " Oil Spot " off Sandy Hook.....	Surface	" "	Ebb	6	Temperature 66°
Sandy Hook bay, off Shrewsbury river.....	Surface	" 13	Flood	18	
Sandy Hook bay, in Horseshoe.....	Surface	" "	Flood	22	
Shrewsbury river, Spermaceti cove.....	Surface	" "	Flood	23	
Shrewsbury river, Seabright drawbridge.....	Surface	" "	Flood	32	
Bodine creek at mouth.....	Surface	" 17	Ebb	34	
Lower bay, off Sandy Hook.....	Surface	" 21	Ebb	10	
Lower bay, Ambrose channel.....	Surface	" "	Flood	8	
Lower bay, off Coney Island.....	Surface	" 14	Ebb	16	
Rockaway inlet.....	Surface and 10 feet	June 29	Ebb	16	6 readings at 3 stations
Rockaway inlet.....	Surface and 10 feet	July 1	Flood	8	
Jamaica bay, off Bell Harbor dock.....	Surface	June 29	Flood	14	
Jamaica bay, off Bell Harbor dock.....	10 feet	" "	Flood	14	
Jamaica bay, off Edgemere.....	Surface	" "	Flood	28	
Jamaica bay, off Canarsie.....	Surface	July 1	Flood	8	
Narrows, midstream.....	Surface	Dec. 15	Slack high water	18	
	96	" "	Slack high water	16	
Craven shoal, bell buoy.....	Surface	" "	Ebb	16	
	80	" "	Ebb	14	
Outer end Ambrose channel.....	Surface	" "	Ebb	4	
	55	" "	Ebb	4	
Narrows, midstream.....	Surface	" 23	Ebb	24	
	48	" "	Ebb	20	
	96	" "	Ebb	24	
Off Norton Point.....	Surface	" "	Ebb	16	
	24	" "	Ebb	8	
Rockaway inlet, gas buoy.....	Surface	" "	Flood	10	
	45	" "	Flood	10	

The waters of Rockaway inlet appear to have been well mixed from top to bottom, but at most points the surface water contained from two to four per cent. more land water than was present at the bottom.

The Narrows. On December 28, 1909, a series of observations was made at the Narrows to determine the per cent. of land water at different depths and stages of tide in the middle and at each side of the channel. The samples were collected on an imaginary line drawn between the tide gauge at Fort Hamilton and Fort Wadsworth Light. The results are summarized in Table V.

TABLE V

PERCENTAGE OF LAND WATER AT DIFFERENT DEPTHS BELOW THE SURFACE AT THE NARROWS DURING THE EBB CURRENT DECEMBER 28, 1909.

Time	50 feet from west side			Middle of channel			50 feet from east side		
	Surface	Mid-depth	Bottom	Surface	Mid-depth	Bottom	Surface	Mid-depth	Bottom
11 A.M.	..	..	..	..	..	..	14	12	14
11.08 A.M.	..	..	..	18	14	14	..	..	..
11.20 A.M.	20	16	16	..	..	..	..	..	..
11.45 A.M.	..	..	..	..	..	..	18	14	16
12.25 A.M.	..	..	..	20	16	16	..	..	..
12.40 A.M.	16	16	16	..	..	..	..	..	..
1.25 P.M.	..	..	..	..	..	..	16	16	16
1.10 P.M.	..	..	..	16	16	14	..	..	..
2.15 P.M.	20	20	20	..	..	..	..	..	..
2.25 P.M.	..	..	..	20	20	20	..	..	..
2.40 P.M.	..	..	..	..	..	..	18	16	18
3.00 P.M.	18	20	20	..	..	..	..	..	..
3.20 P.M.	..	..	..	18	20	18	..	..	..
3.25 P.M.	..	..	..	..	..	..	20	18	18

The depth on the west side was about 70 feet; in the channel it was 100 feet, and on the east side it was 18 feet.

In every case the greatest proportion of land water was found at the surface, but the least amount on the east side was frequently found at mid-depth.

Robbins Reef. Several tests of salinity were made at the proposed location of the Passaic valley sewer near Robbins Reef. The results of two days' work are summarized in Table VI.

TABLE VI

PERCENTAGE OF LAND WATER AT DIFFERENT DEPTHS BELOW THE SURFACE AT ROBBINS REEF AUGUST 23 AND SEPTEMBER 1, 1909.

Date, 1909	Time	Surface	20 feet depth	40 feet depth
August 23.....	10.45 A.M.	40	36	28
	12 Noon	34	30	24
	1.15 P.M.	34	26	24
	2.00 P.M.	32	28	26
	3.00 P.M.	34	24	24
	3.30 P.M.	28	26	20
	4.15 P.M.	32	24	20
September 1.....	11.00 A.M.	20	16	16
	12 Noon	24	20	20
	1.00 P.M.	26	22	22
	2.00 P.M.	22	24	22
	3.15 P.M.	24	26	24
	4.15 P.M.	28	26	26

The difference between the salinity of the water at the surface and at a depth below the surface of 40 feet was found more marked at Robbins Reef than in most other places, the surface sometimes containing 10 per cent. more land water than that near the bottom, but this condition was variable. A sample taken at Robbins Reef October 30, at 4 p. m., had a specific gravity of 1.025, indicating an entire absence of land water. Perhaps this exceptional condition should be accounted for by supposing that a temporary diversion of water took place from the more salty underrun to the surface.

A series of observations was made at Robbins Reef during the month of December, 1909, at times of slack high water and slack low water, for purposes of comparison. The results showed that there was no marked difference in the average salinity at the two stages of tide at this point. The amount of land water at slack high water varied from 14 to 32.4 per cent. and at slack low water from 12 to 36.4 per cent.

In Appendix No. 15 of the report of the United States Coast and Geodetic Survey for 1887, p. 303, there is a table from which the percentages of land water for each lunar hour of tide have been calculated for the Narrows, as shown in Table VII.

Under normal conditions the ebb current began during the 10th lunar hour.

DATA COLLECTED

TABLE VII

PERCENTAGE OF LAND WATER AT THE NARROWS AT ALL HOURS ACCORDING TO THE UNITED STATES COAST AND GEODETIC SURVEY

Lunar Hour	Per Cent.	Lunar Hour	Per Cent.
0.	45.2	VI.	40.0
I.	45.2	VII.	36.4
II.	57.6	VIII.	34.0
III.	64.4	IX.	32.8
IV.	60.4	X.	33.6
V.	56.0	XI.	33.2

From Table VII the percentage of land water may be calculated to range from 38.4 to 22.0 at a depth of 25 feet below the surface and from 26.4 to 14.4 at a depth of 45 feet.

Upper Bay, Kill van Kull and Arthur Kill. A series of observations was made between the Battery and Perth Amboy on December 17, 1909, with the results shown in Table VIII.

TABLE VIII

PERCENTAGE OF LAND WATER AT THE SURFACE AND BOTTOM OF THE CHANNEL THROUGH THE UPPER BAY, KILL VAN KULL AND ARTHUR KILL

Time	Location	Depth in feet	Surface	Bottom	Current
9.55 A.M.	Mouth of Hudson river.	50	34	30	Flood
10.40 A.M.	Upper Bay, 300 feet north Greenville whistling buoy.	52	30	24	Flood
11.25 A.M.	Kill van Kull, between Staten Island and Bergen Point. ...	60	28	28	Flood
11.40 A.M.	Kill van Kull, opposite Shooters Island.	20	50	34	Flood
12.05 P.M.	Arthur Kill, Elizabethport.	27	44	44	Flood
12.50 P.M.	Arthur Kill, south of Rahway river.	25	44	40	Flood
1.55 P.M.	Raritan river, Jersey Central bridge.	26	48	34	Ebb

Pier A, North River. Salinometer observations were made at Pier A at the Battery at noon and 4 P. M. each day from October 15 to November 9, inclusive, the total number of tests in these series being 37. The average amount of land water varied from 19.6 to 38.0 per cent. and averaged 26 per cent. Observations made at the same hours at Governors Island, opposite Pier A, showed that the salinity varied from

17.6 to 37.2, averaging 23.4 per cent. The higher salinity at Governors Island was due to the fact that the waters from the East river flow past this part of the island, while the influence of the less saline discharge from the Hudson is diverted toward the east. The result was a difference of two and one-half per cent. more land water at Pier A than at Governors Island.

Hudson River, from the Battery to Tarrytown. A series of observations was made on the last of the flood and the first of the ebb current along the channel of the Hudson river from opposite Pier A to Tarrytown December 14, 1909. Samples were taken at nine places from the surface, mid-depth and bottom. Table IX gives the percentages of land water found.

TABLE IX

PERCENTAGE OF LAND WATER IN THE HUDSON RIVER FROM THE BATTERY TO TARRYTOWN
DECEMBER 14, 1909

Time	Location Opposite	Depth	Surface	Mid-depth	Bottom
10.00 A.M.	Pier A.....	52	22	22	22
11.05 A.M.	110th street.....	60	30	30	30
11.35 A.M.	Fort Washington Point.....	56	34	36	34
12.20 P.M.	Mt. St. Vincent.....	50	50	44	42
1.17 P.M.	Hastings.....	50	60	52	50
1.35 P.M.	Dobbs Ferry.....	50	66	58	56
2.30 P.M.	Tarrytown Light.....	20	70	64	60

Table X gives the results of a second series of samples collected during an ebb current on December 22, 1909, from the Hudson from the Battery to Tarrytown.

TABLE X

PERCENTAGE OF LAND WATER IN THE HUDSON RIVER FROM THE BATTERY TO TARRYTOWN
DECEMBER 22, 1909

Time	Location Opposite	Depth	Surface	Mid-depth	Bottom
9.30 A.M.	Pier A.....	55	30	26	26
10.30 A.M.	39th street.....	75	48	38	40
11.20 A.M.	110th street.....	50	52	50	48
12.10 P.M.	Fort Washington Point.....	50	56	56	54
1.15 P.M.	Mt. St. Vincent.....	45	64	62	62
2.00 P.M.	Harriman.....	46	66	64	64

The difference in the amount of land water in the Hudson at the two stages of tide was marked. At Mt. St. Vincent, for example, there was 14 per cent. more land water at the surface and 20 per cent. more at the bottom on the ebb current than at slack high water. The difference between the salinity of the water at the surface and at the bottom was usually two or three per cent. It varied from 0 to 10 per cent. more in the surface samples than in the samples collected below.

To ascertain the salinity of the water in different parts of a cross section of the Hudson river a series of samples was taken at Fort Washington Point December 29, 1909. Water was collected from the middle of the river 100 feet from the east shore and 200 feet from the west shore, the depths to the bottom being from 100 to 155 feet, about 15 feet and about 40 feet respectively. The results are condensed in Table XI.

TABLE XI

PERCENTAGE OF LAND WATER AT DIFFERENT POINTS ACROSS THE HUDSON AT FORT WASHINGTON POINT

Time	Current	200 feet from west shore			Mid-stream			100 feet from east shore		
		Surface	Mid-depth	Bottom	Surface	Mid-depth	Bottom	Surface	Mid-depth	Bottom
11.10 A.M.	Flood	..	..	..	..	..	..	40	40	38
11.25 A.M.	Flood	50	42	46	..	..	..	..	..	..
11.35 A.M.	Flood	..	..	..	48	40	40	..	..	..
12.05 P.M.	Flood	..	..	..	..	..	..	44	40	40
12.20 P.M.	Slack	..	..	..	48	44	40	..	..	..
12.45 P.M.	Flood	44	40	40	..	..	..	..	..	..
1.10 P.M.	Ebb	..	..	..	..	..	..	42	40	40
1.40 P.M.	Ebb	..	..	..	44	40	40	..	..	..
1.45 P.M.	Ebb	44	42	40	..	..	..	..	..	..
2.10 P.M.	Ebb	..	..	..	..	..	..	42	38	38
2.40 P.M.	Ebb	..	..	..	44	42	42	..	..	..
2.55 P.M.	Ebb	48	44	42	..	..	..	..	..	..
3.00 P.M.	Ebb	..	..	..	..	..	..	50	40	40
3.10 P.M.	Ebb	..	..	..	50	50	48	..	..	..
3.25 P.M.	Ebb	50	44	44	..	..	..	..	..	..
3.40 P.M.	Ebb	..	..	..	..	..	..	52	46	44

The average percentages of land water were : West side 43.7, mid-stream 42.7, east side 40.5.

The average percentages of land water were: West side 43.7, midstream 42.7, east side 40.5.

Harlem River. Two series of surface samples were collected from the Harlem river July 15, 1909, one at the end of the ebb and one at the first of the flood current. The results are condensed in Table XII.

TABLE XII
PERCENTAGE OF LAND WATER IN THE HARLEM RIVER JULY 15, 1909

	Time	Location	Per Cent.
Ebb current.....	12.30 P.M.	East 109th street.....	34
	1.25 P.M.	East 155th street.....	36
	1.50 P.M.	East 207th street.....	36
	2.15 P.M.	Spuyten Duyvil creek at Spuyten Duyvil.....	38
Flood current.....	3.30 P.M.	Spuyten Duyvil creek at Spuyten Duyvil.....	64
	3.45 P.M.	East 207th street.....	44
	4.10 P.M.	East 155th street.....	36
	4.50 P.M.	East 109th street.....	32

The marked difference which existed between the samples collected at Spuyten Duyvil probably was due to the first sample containing water from the East river, while the second, which was collected an hour and a quarter later, probably contained mostly Hudson river water. At One Hundred and Ninth street the sample in each case was, apparently, East river water.

East River and Long Island Sound. Numerous tests of salinity were made of the water of the East river. The most important of these are given in Table XIII.

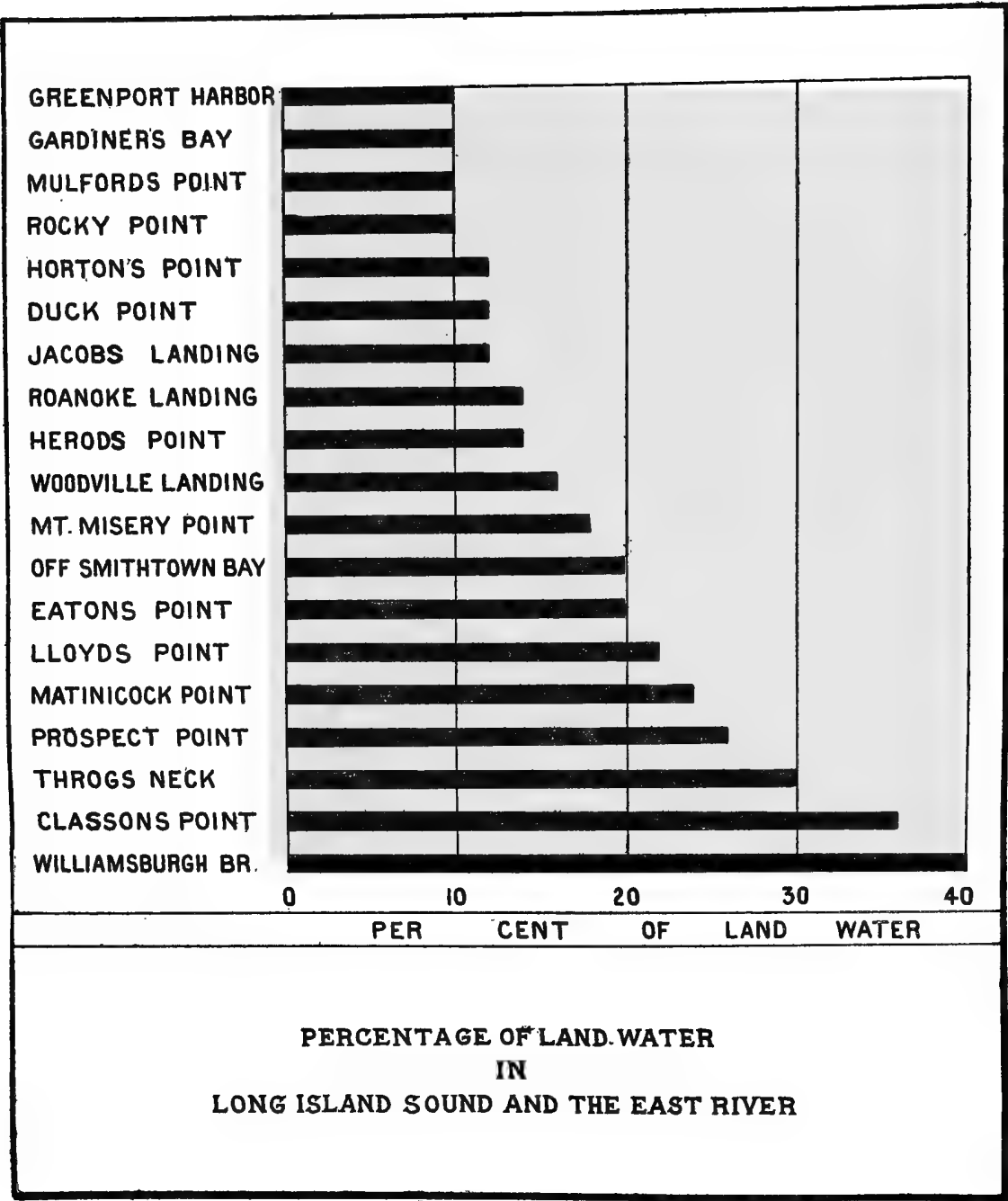
DATA COLLECTED

TABLE XIII

PERCENTAGE OF LAND WATER IN THE EAST RIVER, DECEMBER, 1909

Date, 1909	Time	Current	Location	Depth	Surface	Mid-depth	Bottom
December 16	10.20 A.M.	Flood	Off Ferry dock, Governors Island..	42	28	30	28
	10.30 A.M.	Flood	Brooklyn Bridge	70	32	30	30
	11.00 A.M.	Flood	Queensboro Bridge, west channel..	65	32	32	32
	11.30 A.M.	Flood	West of Randalls Island.....	26	28	28	24
	11.40 A.M.	Flood	Hell Gate	40	30	32	32
	12.30 P.M.	Ebb	College Point	90	22	20	22
	12.50 P.M.	Ebb	Throgs Neck.....	120	20	18	16
	1.50 P.M.	Ebb	Execution Rocks.....	158	16	16	16
December 20	10.40 A.M.	Flood	Brooklyn Bridge.....	63	20	..	12
	11.10 A.M.	Flood	Queensboro Bridge.....	75	20	..	6
	1.35 P.M.	Flood	Throgs Neck.....	60	10	..	10
December 21	10.35 A.M.	Slack	East 83d street.....	43	16	..	14
	12.45 P.M.	Flood	Hell Gate.....	48	20	..	18
	3.25 P.M.	Flood	Tallman Island.....	48	16	..	14
December 22	9.10 A.M.	Ebb	Classon Point	43	14	..	12
	11.15 A.M.	Ebb	Hunts Point.....	30	16	..	14
	11.45 A.M.	Flood	Off Hunts Point.....	34	14	..	12
	1.30 P.M.	Flood	Off Classon Point.....	42	18	..	14
	2.20 P.M.	Flood	Off Whitestone Light.....	45	16	..	14
	3.45 P.M.	Flood	Throgs Neck.....	105	14	..	12
December 23	8.50 A.M.	Ebb	Throgs Neck.....	43	10	..	8
	2.40 P.M.	Ebb	Stepping Stones.....	74	12	..	10

The currents in the lower East river cause a rather thorough mixing of the water but toward the Sound a difference between the surface and bottom is observable. There is, in general, a decrease in land water toward the east. This is well illustrated in a series of samples taken through Long Island Sound and the East river April 13 and 15, 1909. All the samples were collected at the surface. Table XIV gives the results in condensed form.



DATA COLLECTED

TABLE XIV

PERCENTAGE OF LAND WATER IN LONG ISLAND SOUND AND THE EAST RIVER
APRIL 13 AND 15, 1909

Date, 1909	Time	Current	Location	Per Cent. Land Water
April 13.	5.00 A.M.	Ebb	Greenport harbor.....	10
	8.00 A.M.	Ebb	Rocky Point.....	10
	9.00 A.M.	Ebb	Hortons Point.....	12
	11.00 A.M.	Flood	Jacobs Landing.....	12
	12.00 M.	Flood	Roanoke Landing.....	14
	1.00 P.M.	Flood	Herods Point.....	14
	2.00 P.M.	Flood	Woodville Landing.....	16
	3.00 P.M.	Flood	Mount Misery Point	18
April 15.	4.15 A.M.	Flood	Smithtown bay.....	20
	5.00 A.M.	Flood	Eatons Point.....	20
	6.00 A.M.	Flood	Lloyds Point.....	22
	7.00 A.M.	Flood	Matinicoek Point.....	24
	8.00 A.M.	Ebb	Prospect Point.....	28
	9.00 A.M.	Ebb	Throgs Neck.....	30
	10.00 A.M.	Ebb	Classon Point	36
	11.00 A.M.	Ebb	Williamsburg bridge.....	40

CHAPTER XIV

CONDITION OF THE SEWERS OF MANHATTAN AS SHOWN BY INSPECTIONS

Early in the year 1910, an inspection of the principal sewers of Manhattan was made by the Metropolitan Commission in co-operation with the Bureau of Sewers. The conditions found are briefly summarized in the following pages.

The sewers were entered at two hundred and forty-six places. The results were recorded on blank forms supplied for the purpose. It was found that in many cases there had been a settlement of the sewer resulting in a crack in the centre of the arch. House connections to the sewers were often poorly made and bricks had fallen out around the pipe at the connection. The marginal sewers were in need of cleaning. Black mud varying in depth up to three feet was found, which in many cases was in a putrefactive condition, giving off bubbles of foul gases when disturbed. A few serious cases of erosion were found. The grade of many sewers was flat and not sufficient to prevent fouling and septic action. In several cases bad breaks were discovered.

Equipment and Method of Inspection. The principal trunk sewers and their important connections were inspected at intervals of about two blocks. It was the custom to enter a manhole at or near a street intersection and go through the sewer to the next manhole, usually a distance of about sixty feet. One of the men of the Bureau of Sewers went ahead of the observer and one followed in the rear. An electric flash light was used to illuminate the sewer and a small two-foot iron rod was carried to make examinations of the invert and sides of the sewer. Table I contains a list of the outlets of the sewers inspected.

TABLE I
OUTLETS OF SEWERS INSPECTED

East River	Hudson River	Harlem River
Roosevelt street	Dyckman street	135th street
Oliver street	171st street	151st street
Jefferson street	130th street	201st street
Rivington street	129th street	
14th street	96th street	
18th street	80th street	
21st street	66th street	
33d street	42d street	
42d street	26th street	
49th street	23d street	
62d street	20th street	
74th street	17th street	
79th street	Clarkson street	
95th street	Canal street	
106th street		
110th street		

Note. In addition to the above mentioned sewers, inspections were made of the marginal sewers below Fourteenth street on the west side and below Jackson street on the east side.

Erosion. Few cases where the bricks of the invert were actually worn away were found. In a few places in the upper west side of Manhattan the up-stream edges of the bricks were rounded off as a result of high velocity of sewage.

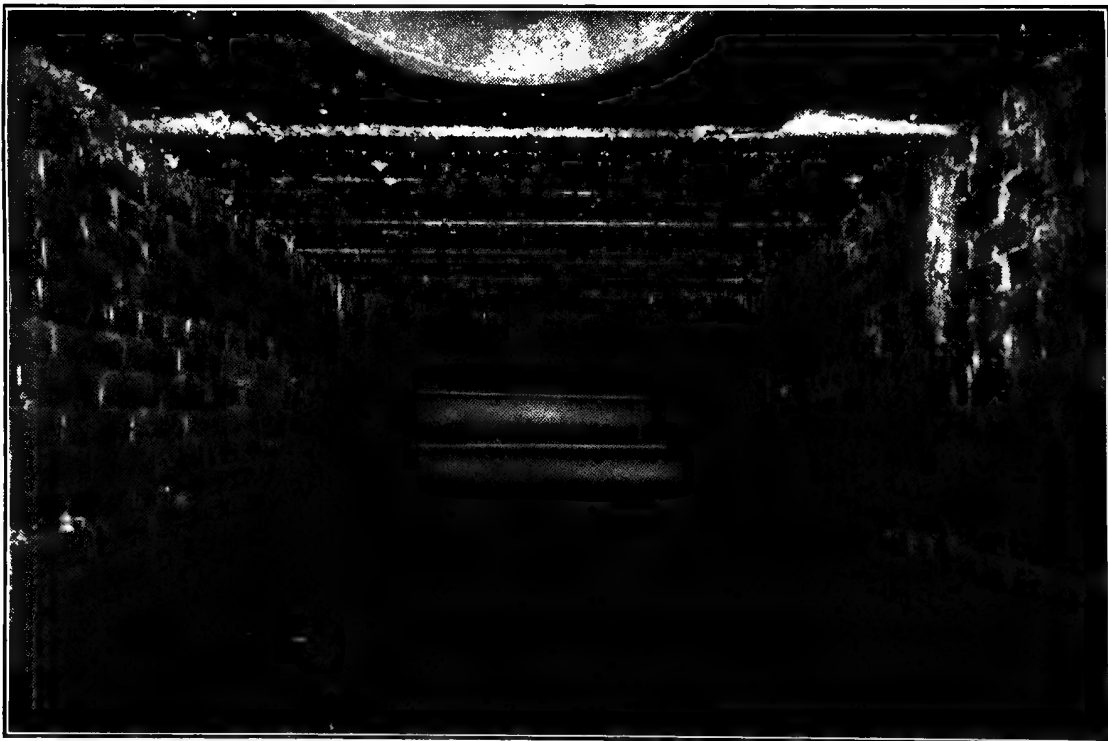
In a large number of the sewers the mortar was worn from the joints in the brick-work of the invert. Sometimes the mortar has been worn away only to a slight depth while at other places it has been cut out by the sewage to the full depth of the brick. Table II gives the location and nature of the erosion.



Sewer Inspecting Gang. Inspectors for the Metropolitan Commission went through many of the sewers in Manhattan in order to determine their condition



Interior of a New York sewer showing broken walls. Many of the old sewers were poorly built and some are in danger of collapse



Obstruction of sewer consisting of two transversely laid water pipes. In many places the sewers of Manhattan have been broken into and obstructed by pipes, beams, walls, etc.

TABLE II
EXAMPLES OF EROSION

Inspection No.	Location		Conditions Found
	On	At	
17	Jefferson street.....	Henry street.....	{ Bricks in invert eroded in one case to depth of about $\frac{3}{8}$ -inch Edges of bricks in invert and sides of sewer rounded off on up-stream side
72	63d street.....	First avenue.....	
73	63d street.....	Avenue A.....	Bricks rounded off by erosion
119	165th street.....	Fort Washington avenue.	Up-stream edge of bricks rounded off $\frac{3}{8}$ -inch
123	130th street.....	Broadway.....	Up-stream edges of bricks rounded off $\frac{1}{2}$ -inch
124	130th street.....	{ 150th street east of River- side drive..... }	Up-stream edges of bricks rounded off $\frac{1}{2}$ -inch

Steam. Two well defined areas in which steam is present exist. These areas occur in the parts of the city where there are large buildings used for office and business purposes. In these areas steam almost constantly issues from the manholes in the streets and often from the openings to the catch basins and is a nuisance to passers-by, and a source of danger to employees of the sewer department. It is impossible to inspect some sewers because of the presence of steam.

Deposits. The grade of many of the Manhattan sewers is necessarily flat and in most of these deposits were found. The marginal sewers contain foul black mud and those in the lower east side of Manhattan Island carry much household waste consisting of paper, rags, grease, etc. In several of the Harlem sewers there are extensive deposits of marble dust from stone-working plants. In the Nagle avenue sewer there is a deposit of sand and gravel about 36 inches deep which is said to have been washed in during the construction of the sewer.

In this connection it is important to note that sticks, stones, etc., have evidently been dumped through manholes when snow has been disposed of by putting it into the sewers. Many examples were found where material introduced in this way made an obstruction and held back lighter material, thus forming a deposit which otherwise would not exist.

It was observed in some cases that there were deposits of material that looked like street cleanings beneath manholes and that there was less depth of deposit in the sewers at points removed from them. This suggested that the employees of the Street Cleaning Department had disposed of the sweepings from the streets by putting them in the sewers.

Extensive deposits of grease were found covering the arch of many of the sewers of the lower east side; this grease in many cases was hung with festoons of mold, called "lace curtains" by the sewer men from their draping effect and white color. This deposit had a maximum thickness of one foot in the Jefferson street sewer at Water street.

In the Washington Heights district there is an extensive infiltration of ground water which results in the deposit of a reddish brown material on the sides and arch of the sewer. The maximum thickness of this deposit is about one inch. Table III gives the nature, amounts and location of the principal deposits found in the sewers.

TABLE III
DEPOSITS IN THE SEWERS

Inspection No.	Location		Conditions Found
	On	At	
	GREASE		
3	Roosevelt street.....	West of Cherry street....	Grease, thickness, 6 inches
4	Roosevelt street.....	South.....	Sand and gravel, 10 inches
8	Oliver street.....	South.....	Gravel, etc., slight
18	Jefferson street.....	South of Monroe street....	Grease
19	Jefferson street.....	Water street.....	Grease, maximum thickness, 1 foot
35	14th street.....	Avenue B.....	Gravel, etc., 3 inches
36	14th street.....	Avenue C.....	Grease, maximum thickness, 2 inches
38	14th street.....	Avenue D.....	Grease, maximum thickness, 3 inches
42	18th street.....	Avenue A.....	Grease, thickness, 1 inch
43	18th street.....	Avenue B.....	Grease, thickness, 1 inch to 2 inches
44	18th street.....	Avenue C.....	Grease
54	33d street.....	Marginal street.....	{Mud and gravel, 6 inches Grease, about 3 inches
55	33d street.....	First avenue.....	Grease, thickness, 4 inches
62	42d street.....	Third avenue.....	Grease, thickness, $\frac{3}{8}$ -inch
89	95th street.....	First avenue.....	Grease, thickness, $\frac{1}{2}$ -inch
97	110th street.....	Second avenue.....	Grease, in patches, 1 inch thick
102	135th street.....	Fifth avenue.....	{Grease, deposits look like hornets' nests. Maximum thickness, 6 inches
	PROBABLY FROM SNOW DUMPED INTO THE SEWER		
12	Mulberry street.....	Park street.....	Dam formed 18 inches high
48	22d street.....	First avenue.....	Stones and debris, depth, 1 foot
56	34th street.....	First avenue.....	A 5-pound rock in sewer at manhole
57	34th street.....	Second avenue.....	An 8-pound flagstone in sewer at manhole
97	110th street.....	Second avenue.....	Stones, rags, etc., depth, 1 foot

TABLE III—*Continued*

Inspection No.	Location		Conditions Found
	On	At	
	OTHER	DEPOSITS	
3	Roosevelt street.....	Cherry street.....	Gravel and sand, depth 11 inches
22	Rivington street.....	Mangin street.....	Brick, clinker, etc., depth 12 inches
46	21st street.....	Marginal street.....	Mud and cinders, depth 12 inches
68	67th street.....	East of Third avenue....	Five inches of cement
71	64th street.....	First avenue.....	Broken manhole cover
87	95th street.....	Second avenue.....	Mud, cinders, etc., depth 12 inches
96	110th street.....	West of Third avenue....	Rags, stone, brick, mortar, depth 8 inches
97	110th street.....	East of Second avenue...	Rags, stone, brick, depth 1 foot
106	147th street.....	Eighth avenue.....	Mud, depth 2 to 3 feet
109	Nagle avenue.....	Dyckman street.....	Sand and gravel, depth 2 to 3 feet
110	Nagle avenue.....	Academy street.....	Sand and gravel, depth 3 feet
111	Academy street.....	East of Nagle avenue....	Mud and sand, depth 15 inches
114	Broadway.....	Nagle avenue.....	Reddish incrustation, 1½ inches thick
121	Riverside drive.....	¼ mile north of 165th street	Mushroom-like growths on sides of sewer
130	Amsterdam avenue.....	100th street.....	{ Reddish brown and whitish incrustations, thickness ½ inch
133	96th street.....	Riverside drive.....	Substance like mortar on invert, depth 2 inches
135	104th street.....	East of Second avenue....	Marble dust, depth 16 inches, from stone yard
146	Broadway.....	69th street.....	{ Gravel and mud, depth 3 to 12 inches, evidently came in through old house connection
151	Ninth avenue.....	41st street.....	Mud and gravel, depth 6 to 12 inches
154	42d street.....	{ 100 feet west of Eleventh avenue.....	{ 10-pound stones on invert
168	Clarkson street.....	{ 300 feet west of Varick street.....	{ Heavy stones and house wastes, depth up to 12 inches
170	Canal street.....	West of Lafayette street..	Mud, depth 18 inches
183	West street.....	Gansevoort street.....	{ Gravel and wastes from West Washington Market, depth 13 inches
184	West street.....	Bethune street.....	Mud, depth 2 feet
185	West street.....	Charles street.....	Mud, depth 18 inches
187	West street.....	West Houston street.....	Mud, depth 8 inches
190	West street.....	Springstreet.....	Mud, depth 22 inches
191	West street.....	Desbrosses street.....	Mud, depth 12 inches
194	Franklin street.....	West of Church street....	Mud, rags, etc., depth, 8 inches
198	West street.....	Hubert street.....	11 inches, mud
200	West street.....	Duane street.....	10 inches, mud
202	West street.....	South of Vesey street....	8 inches, mud
203	West street.....	North of Cortlandt street.	12 inches, mud
204	West street.....	Albany street.....	10 inches, mud, rags, etc.

TABLE III—*Continued*

Inspection No.	Location.		Conditions Found
	On	At	
	OLD DEPOSITS		
206	West street.....	South of Rector street...	18 inches, mud and house wastes
214	South street.....	Clinton street.....	12 inches, mud
215	South street.....	North side Rutgers slip...	12 inches, mud
216	South street.....	South side Pike slip.....	28 inches, mud, rags, etc.
218	South street.....	Catherine slip.....	10 inches, mud
219	South street.....	James slip.....	11 inches, mud
225	South street.....	South of Peck slip.....	10 inches, mud
226	South street.....	Fulton street.....	18 inches, mud
227	South street.....	South side Maiden lane...	10 inches, mud
228	South street.....	North side of Wall street.	12 inches, mud
229	South street.....	North side of Old slip....	21 inches, mud
235	15th street.....	East of Avenue A.....	{ Old house connection has pile of dirt one foot high in front of it
237	15th street.....	West of Avenue C.....	
241	Avenue C.....	South of 9th street....	Mud, gravel, bricks, etc., 12 inches.
243	2d street.....	West of Avenue B.....	9 inches, mud
246	Fulton street.....	William street.....	{ Pile of mortar and brick beneath catch basin connection. Height of pile 18 inches.

Odors. Except where there was some local odor that was very marked, the odor encountered was the distinctive, musty smell usually found in sewers. In the Canal street sewer an odor of banana oil was very noticeable. Illuminating gas was present in many cases, oftentimes in such large amounts that it was unsafe to light a candle. In some of the sewers containing putrefactive mud, the odor of hydrogen sulphide was recognized. A fecal odor was noticed chiefly in the sewers of the lower east side, in which district the sewage is very concentrated. Table IV gives the nature and location of the most pronounced local odors observed.

TABLE IV

EXAMPLES OF LOCAL ODORS

Inspection No.	Location		Remarks
	On	At	
18	Jefferson street.....	Monroe street.....	Strong odor of illuminating gas
19	Jefferson street.....	Water street.....	Strong odor of illuminating gas
22	Rivington street.....	Mangin street.....	Strong odor of illuminating gas
26	Rivington street.....	Attorney street.....	Slight odor of illuminating gas
27	Rivington street.....	Suffolk street.....	Slight odor of illuminating gas
35	14th street.....	East of Avenue B.....	Strong odor of illuminating gas
36	14th street.....	East of Avenue C.....	Strong odor of illuminating gas
38	14th street.....	Avenue D.....	Illuminating gas
58	34th street.....	West of Third avenue....	Strong odor of illuminating gas
68	67th street.....	East of Third avenue....	Strong fecal odor
69	67th street.....	Second avenue.....	Strong fecal odor
76	74th street.....	Lexington avenue.....	Sewer gas, strong
77	74th street.....	East of Third avenue....	Strong odor of illuminating gas
80	79th street.....	East of Park avenue....	Sewer gas, strong
81	79th street.....	East of Third avenue....	Illuminating gas and sewer gas
86	Second avenue.....	92d street.....	Hops and brewery wastes
87	95th street.....	Second avenue.....	Hops and brewery wastes
88	96th street.....	Second avenue.....	Strong fecal odor
90	95th street.....	East river.....	Odor of hops in sewage at outlet
91	106th street.....	East of Fifth avenue....	Fecal odor
92	106th street.....	East of Park avenue....	Hydrogen sulphide
95	110th street.....	Madison avenue.....	Fecal odor
99	125th street.....	Fifth avenue.....	Strong fecal odor
101	131st street.....	Fifth avenue.....	Illuminating gas
106	147th street.....	Eighth avenue.....	Hydrogen sulphide and fecal odor
127	129th street.....	Amsterdam avenue.....	Fecal odor
128	Amsterdam avenue.....	South of 110th street....	Hydrogen sulphide, sewer gas, illuminating gas
138	Park avenue.....	87th street.....	Illuminating gas and gasolene
143	81st street.....	Broadway.....	Gasolene, moderate
148	66th street.....	Amsterdam avenue.....	Strong illuminating gas
170	Canal street.....	West of Lafayette street..	Banana oil
171	Canal street.....	Church street.....	Banana oil

DATA COLLECTED

TABLE IV—*Continued.*

Inspection No.	Location		Remarks
	On	At	
176	20th street	West of Third avenue...	Strong odor of illuminating gas
187	West street	Leroy street	Hydrogen sulphide
190	West street	Spring street	Fecal odor
199	West street	South of Franklin street..	Fecal odor
212	South street	South of Jackson street ..	Fecal odor
213	South street	Gouverneur slip	Fecal odor
215	South street	North side of Rutgers slip.	Hydrogen sulphide
221	Seventh street	Third avenue	Fecal odor
225	South street	South of Peck slip	Hydrogen sulphide
226	South street	Fulton street	Hydrogen sulphide
227	South street	South side Maiden lane ..	Hydrogen sulphide
228	South street	North side Wall street ...	Hydrogen sulphide
230	South street	Coenties slip	Hydrogen sulphide
236	15th street	Avenue B	Illuminating gas
237	15th street	West of Avenue C	Illuminating gas
242	2d street	East of Avenue A	Fecal odor

Obstructions. In some cases water and gas pipes pierce the sewers. At Sixth avenue and Ninth street the sewer is obstructed by a 20-inch main and a 12-inch pipe directly below it. On Twenty-sixth street east of Sixth avenue about 75 per cent. of the sewer area is taken up by an obstruction of iron beams and brickwork. On Tenth avenue near Twenty-third street the wood forms put in to build the arch of the sewer and a curtain wall supporting them were found still in place and nearly obstructing the whole sewer area.

Table V shows the location and nature of the obstructions discovered.

TABLE V
OBSTRUCTIONS

Inspection No.	Location		Condition Found
	On	At	
153	42d street	{ 75 feet east of Tenth avenue	Iron beams project down 2½ feet below arch
161	23d street		Iron beams project down 14 inches below arch
162	23d street	West of Ninth avenue...	Iron beams project down 18 inches below arch

TABLE V—*Continued*

Inspection No.	Location		Condition Found
	On	At	
162	23d street	West of Ninth avenue....	A 12-inch water pipe crosses sewer
166	Sixth avenue.....	9th street.....	{ A 12-inch water main with a 20-inch pipe above, cross sewer here
171	Canal street.....	Church street.....	A 12-inch pipe projects 10 inches below arch
172	Canal street.....	East of Sullivan street...	{ Iron beams project 18 inches below arch. 12-inch pipe here, its bottom is 24 inches below crown of arch
180	26th street.....	East of Sixth avenue....	{ About 75 per cent. of sewer area taken up by brick obstruction extending 19 inches below arch of sewer
192	Franklin street.....	East of W. Broadway....	A 12-inch pipe crosses sewer 2½ feet above invert
195	Worth street.....	East of W. Broadway....	{ A 6-inch iron house pipe projects into sewer for 8 inches above invert
222	8th street.....	Avenue C.....	A 6-inch water main projects 1 foot below arch
224	8th street.....	East of Lewis street.....	{ A 1-inch pipe from hydrant projects 2 feet into sewer below arch
231	South street.....	Moore street.....	A 6-inch pipe projects 5 inches below arch
237	15th street.....	West of Avenue C.....	Top of 12-inch water pipe is 5 inches below arch
239	Tenth avenue.....	North of 23d street.....	{ Sewer obstructed by wood forms and brick work supporting them

Cracks. A large number of the sewers inspected had cracks in the centre of the arch. In a few cases, as on Forty-second street near Eleventh avenue, there were two longitudinal cracks in the arch about two feet apart, resulting in a depression and flattening of the brickwork between the two parallel cracks. The cracks varied from a width scarcely discernible up to a width of one and one-half inch. The cracks were usually widest in the circular sewers though there were large cracks in many of those with an egg-shaped cross-section.

Table VI gives the location and nature of the cracks observed.

TABLE VI
CRACKS

Inspection No.	Location		Conditions Found
	On	At	
35	14th street	East of Avenue B	Crack 10 feet long ; ¼-inch wide in centre of arch
41	18th street	East of First avenue....	Crack ½-inch wide, whole length of section
42	18th street	Avenue A	{ Many cracks ; practically whole length of section ; width, ½ inch to 1 inch
62	42d street	East of Third avenue....	{ Crack in arch all along section ; width, ¼ inch to ½ inch
76	74th street	Lexington avenue	Crack in arch ; width, ¼ inch to ½ inch
78	74th street	West of Avenue A.....	Crack in arch ; width, ¼ inch to ½ inch

TABLE VI—Continued

Inspection No.	Location		Conditions Found
	On	At	
80	79th street	East of Park avenue	Crack in arch ; width, $\frac{1}{4}$ inch
82	79th street	East of Second avenue	Crack in arch ; width, $\frac{1}{4}$ inch
92	106th street	East of Park avenue	{ Crack in arch all along section ; width, $\frac{1}{4}$ inch to $1\frac{1}{2}$ inch
104	145th street	St. Nicholas avenue	Crack in arch $\frac{1}{2}$ inch wide ; length, 30 feet
106	147th street	Eighth avenue	Two cracks in arch, about 2 feet apart, $\frac{1}{4}$ -inch wide
114	Broadway.	Nagle avenue	Crack in arch ; width, $\frac{1}{8}$ -inch
115	Broadway.	Sherman avenue	Slight crack in arch of sewer
117	Broadway.	Dyckman street	$\frac{1}{8}$ -inch crack in arch 50 feet long
129	Amsterdam avenue	105th street	{ Crack in arch $\frac{1}{4}$ -inch to $\frac{3}{8}$ -inch wide ; length about 30 feet
130	Amsterdam avenue	100th street	{ Crack in arch, $\frac{1}{4}$ -inch to $\frac{1}{2}$ -inch wide over most of section inspected
138	Park avenue	87th street	{ Crack in arch $\frac{1}{4}$ -inch to $\frac{1}{2}$ -inch wide ; length about 30 feet
139	Eighth avenue	Between 89th and 90th streets.	{ Crack in arch $\frac{1}{4}$ -inch to $\frac{3}{4}$ -inch wide
141	West End avenue	85th street	{ Crack in arch $\frac{1}{4}$ inch to $\frac{3}{4}$ -inch over most of section inspected
150	Ninth avenue	South of 46th street	Crack in arch, $\frac{1}{4}$ -inch wide, length 20 feet
154	42d street	{ 100 feet west of Eleventh avenue	{ Two parallel cracks in arch, width $\frac{1}{2}$ -inch to $1\frac{1}{2}$ inch
179	26th street	West of Seventh avenue	A $\frac{3}{4}$ -inch crack in arch, length 10 feet
182	Tenth avenue	Opposite Pier 53	Crack in top of 15-inch vitrified pipe sewer
185	West street	Charles street	A $\frac{1}{4}$ -inch crack in arch, length about 20 feet
193	Franklin street	West of Church street	A $\frac{1}{4}$ -inch crack in arch over 20 feet of section inspected
196	Worth street	West of Broadway	Crack in centre of arch, 1 inch wide, 30 feet long
197	Worth street	West of Broadway	Most all joints of arch opened for $\frac{1}{8}$ -inch to $\frac{1}{4}$ -inch
222	8th street	Avenue C	Cracks up to $\frac{3}{4}$ -inch wide
223	8th street	East of Avenue D	Cracks up to $\frac{1}{2}$ -inch
224	8th street	East of Lewis street	Cracks $\frac{1}{4}$ -inch to $\frac{1}{2}$ -inch over most of section inspected
233	15th street	East of Fifth avenue	Crack $\frac{1}{2}$ to $\frac{1}{4}$ -inch wide, length 20 feet
236	15th street	Avenue B	Bad cracks $\frac{1}{2}$ -inch to 1 inch wide over whole section
238	Second avenue	South of 85th street	$\frac{1}{4}$ -inch crack in arch
246	Fulton street	William street	$\frac{1}{4}$ -inch crack in arch, length 30 feet

Defective Brickwork. In many cases the cracks previously mentioned have resulted in such an excessive spreading of the joints that a strip two or three bricks wide of the inner ring of the arch has dropped out.

Several cases were observed, as, for example, at Avenue C and Ninth street, in which both rings of the brickwork have fallen in as well as has the material of the street above, at the location mentioned, exposing the granite paving blocks.



Location of the sewer shown in the cut below



Interior of a sewer showing dangerous condition of brick work. A number of such cases exist calling for extensive and costly repairs



Spent steam escaping from a sewer manhole in Manhattan. On one day's inspection 46 such cases were noted south of Chambers street



Accumulations of grease and mold in a sewer. This condition occurs in certain tide-locked sewers which drain thickly populated tenement districts

On Eighth avenue at Eighty-ninth street a break with an area of about two square feet in the side of the sewer was found; leading from it were tunnels about three inches in diameter, presumably made by sewer rats. Several other cases were observed where the side of the sewer was pierced by rat holes thus forming the beginning of a still larger break.

Table VII gives the location and extent of places where defective brickwork was found.

TABLE VII
DEFECTIVE BRICKWORK

Inspection No.	Location		Conditions found
	On	At	
27	Rivington street.....	West of Suffolk street....	About 10 bricks fallen out of sewer
33	14th street.....	East of First avenue.....	{ 3 bricks out of side of sewer, rat holes leading from break
39	14th street.....	East of Avenue D.....	4 square feet of bricks gone from side of sewer
56	34th street.....	West of First avenue.....	Patches 15 square feet in area out of arch and sides
71	64th street.....	First avenue.....	2 or 3 bricks out of side, rat holes leading from break
73	63d street.....	Avenue A.....	Defective brickwork at junction of sewers.
81	79th street.....	East of Third avenue....	{ Inner ring of arch fallen out of place, 1 foot wide and 30 feet long
93	106th street.....	East of Third avenue....	1 square foot gone from side of sewer
101	131st street.....	Fifth avenue.....	Rough brickwork
139	Eighth avenue.....	{ Between 89th and 90th streets.....	{ Break in side of sewer 2 square feet in area, section distorted
145	80th street.....	{ New York Central Railroad tracks.....	{ 4 square feet of inner ring gone above manhole, 3 square feet gone below
154	42d street.....	{ 100 feet west of Eleventh avenue.....	{ Inner ring of arch gone, place 2 feet wide and 40 feet long
163	23d street.....	East of Seventh avenue..	{ 4 square feet gone in one place, $\frac{1}{2}$ square foot in another
167	Sixth avenue.....	West 3d street.....	4 square feet of bricks out at junction of sewers
173	Canal street.....	Greenwich street.....	{ 3 or 4 bricks have dropped out of arch, 415-pound blocks from side of sewer have fallen out and lie on invert
177	20th street.....	East of Irving place.....	{ Areas of about 1 square foot where bricks are gone from arch
181	26th street.....	West of Broadway.....	{ Both rings gone in two places; combined area about 15 square feet. Inner ring gone in many places
197	Worth street.....	West of Broadway.....	{ In places (2 or 3) bricks have dropped out of inner ring of arch
206	West street.....	Between Rector and Morris	Bricks out of arch
210	13th street.....	East of 6th avenue.....	Bricks dropped out of inner arch ring in 5 places
221	7th street.....	Third avenue.....	{ 2 square feet of invert gone (both rings). Bricks gone from arch
222	8th street.....	Avenue C.....	{ Inner ring of brick gone in many places. Both rings in one case
229	South street.....	North side Old slip.....	Brickwork uneven
234	15th street.....	West of Union Square....	{ Bricks uneven, one course sticks out $\frac{1}{4}$ -inch above lower 3 square feet of brick in inner ring of arch gone
236	15th street.....	Avenue B.....	{ In 4 places bricks have dropped out of inner ring of arch
241	Avenue C.....	South of 9th street.....	{ Both rings gone in 2 places, inner ring gone in many instances
242	2d street.....	East of Avenue A.....	In several places bricks gone from inner ring of arch
246	Fulton street.....	William street.....	4 square feet of brick in crown of arch gone

Distortion. Distortions of the original form of the sewers were numerous. The circular brick sewers were more distorted than those with an egg-shaped cross section. The circular brick sewer on Twenty-sixth street near Eighth avenue is a fair example of distortion of an old circular sewer. Two measurements of the sewer about 20 feet apart were made as shown in the following table:

	1st	2nd
Height	42 inches	45 inches
Width	52 inches	52 inches
Width greater than height due to distortion	10 inches	7 inches

In many cases the distortion has apparently been caused by putting a new arch on an old invert, the result oftentimes being a cross section that is not symmetrical or as regular in outline as it should be.

The distortion sometimes exists without any cracks of noticeable size and seems to be the result of a small amount of spreading or compression at all joints.

Catch Basins. Some catch basins were found to contain deposits of black mud and street sweepings up to depths of five feet. Other basins were clean and contained no deposits.

One catch basin at One Hundred and Sixth street east of First avenue was found to be completely full of pieces of stone from a stone working plant nearby.

Table VIII gives the location and deposits found in the catch basins inspected.

TABLE VIII
CONDITION OF CATCH BASINS

Inspection No.	Location		Depth of Deposit
	On	At	
2	Roosevelt street.....	New Bowery.....	5 feet
12	Mulberry street.....	Park street.....	Recently cleaned out
14	Division street.....	Gouverneur street.....	18 inches
22	Rivington street.....	Goerck street.....	Slight, recently cleaned
27	Rivington street.....	Suffolk street.....	Slight
36	14th street.....	Avenue C.....	2½ feet
47	22d street.....	Avenue A.....	Clean
53	22d street.....	Fourth avenue.....	3 feet
58	34th street.....	West of Third avenue....	6 inches
62	42d street.....	Third avenue.....	Clean

TABLE VIII—*Continued*

Inspection No.	Location		Conditions Found
	On	At	
66	49th street.....	Second avenue.....	16 inches
74	62d street.....	Avenue A.....	3½ feet
76	74th street.....	Lexington avenue.....	12 inches
84	79th street.....	Avenue A.....	18 inches
87	95th street.....	Second avenue.....	2½ feet
90	95th street.....	First avenue.....	2 feet
94	106th street.....	East of First avenue.....	6 inches
94	106th street.....	East of First avenue.....	Full of pieces of stone from stone yard opposite
95	110th street.....	Madison avenue.....	3 feet
99	125th street.....	Fifth avenue.....	18 inches
102	135th street.....	Fifth avenue.....	2 feet
105	145th street.....	Eighth avenue.....	Clean
109	Nagle avenue.....	Dyckman street.....	2 feet
117	Broadway.....	Dyckman street.....	8 inches
123	Broadway.....	130th street.....	3 feet
126	Old Broadway.....	129th street.....	2 feet
129	Amsterdam avenue.....	104th street.....	4 feet
144	80th street.....	Riverside drive.....	2½ feet
148	66th street.....	Amsterdam avenue.....	2 feet
153	42d street.....	Tenth avenue.....	2 feet
157	26th street.....	Tenth avenue.....	2 feet
162	23d street.....	Ninth avenue.....	12 inches
168	Clarkson street.....	Varick street.....	4 inches
172	Canal street.....	Sullivan street.....	Basin clean
174	17th street.....	Tenth avenue.....	2 feet

Sewer Outlets. Most of the trunk sewers inspected discharge near the pierhead line through wood stave pipe. At Tenth street there is no adequate outlet provided, the sewage finding its way out from behind a bulkhead as best it can. At Dyckman street the outlet is through a 20-inch vitrified pipe beneath a building used in the summer as a restaurant, with a bath house adjoining.

CHAPTER XV

ORGANIZATION OF FORCE EMPLOYED

Acknowledgments. The Metropolitan Sewerage Commission, having completed the work required by the Act under which it was created, desires to express its hearty appreciation of the ability, faithfulness and industry of the various technical assistants who have been engaged under its direction in the collection of the data contained in the foregoing pages.

The amount of work accomplished has been large, and the conditions under which it was prosecuted, in many cases, difficult. It is with pleasure that the Commission records here its unqualified commendation of the loyalty and devotion of the members of the staff to their respective duties.

The organization of the force employed since January, 1908, was as follows:

TECHNICAL ASSISTANTS

Names	Titles under Civil Service Classifications	Period of Service	
		Beginning	Ending
Kenneth Allen	Engineer.	July 27, 1908	April 30, 1910
Wm. B. Fuller.....	Engineer.	February 4, 1909	June 12, 1909
W. W. DeBerard.....	Assistant Engineer	September 20, 1909	March 31, 1910
J. E. Hill	Assistant Engineer	August 10, 1908	October 9, 1908
Geo. H. Shaw.....	Assistant Engineer.	September 1, 1909	April 14, 1910
John P. Fox.....	Statistician	May 28, 1908	December 12, 1909
D. S. Merritt.....	Engineer.....	November 18, 1908	January 15, 1910
George Perrine.....	Statistician.....	February 1, 1910	March 3, 1910
Max L. Berrey	Draughtsman.....	February 23, 1909	April 30, 1910
P. F. McClellan.....	Engineering Assistant.....	November 27, 1909	April 30, 1910
Harold A. Brown	Engineering Assistant.....	November 27, 1909	January 15, 1910
R. M. Merriman.....	Engineering Assistant.....	November 17, 1909	November 18, 1909
Payn B. Parsons.....	Bacteriologist	March 1, 1909	April 30, 1910
Raymond H. Pond.....	Biologist	August 17, 1908	July 31, 1909
R. N. Hoyt.....	Biologist	June 20, 1909	January 12, 1910
David Morey.....	Chemist	August 24, 1909	November 27, 1909
S. R. Kelf.....	Stenographer	July 27, 1908	April 30, 1910

DATA COLLECTED

SALINOMETER OBSERVERS

Names	Locations of Stations	Period of Service	
		Beginning	Ending
Nelson L. Ackerman.....	Fort Wadsworth.....	December 1, 1908	December 31, 1909
Sven G. Berglund.....	Ambrose Light.....	September 26, 1908	December 31, 1909
W. W. Byrne.....	Fort Washington.....	December 12, 1908	December 31, 1909
Edmond Delattre.....	Governors Island.....	December 1, 1908	December 31, 1909
Alexander Ferreira.....	Thiogs Neck.....	January 7, 1909	December 31, 1909
August Kjelberg.....	Tarrytown.....	December 11, 1908	December 31, 1909
John Osterdahl.....	Great Beds.....	December 1, 1908	December 31, 1909
John Stone.....	Blackwells Island.....	January 6, 1909	December 31, 1909
Herbert Sisson.....	West Bank.....	November 27, 1908	December 31, 1909
Chas. Swift.....	Governors Island.....	January 1, 1909	December 31, 1909
Jacob Walker.....	Robbins Reef.....	September 18, 1908	December 31, 1909
Mrs. Eliza McCashin.....	Passaic Light.....	January 15, 1909	December 31, 1909

